Indoor Positioning System-A Survey

Priyanka Rajmane[1], Hrishikesh Borkar[2], Aakash Jadhav[3], Vipul Jadhav[4], Arjun Shinde[5]
Department of Computer Engineering
[1]Asst. Professor, Modern Education Society's College of Engineering, Pune
[2,3,4,5] Student, Modern Education Society's College of Engineering, Pune

Abstract- *This paper aims to provide the reader with review of technologies,techniques and algorithms used to implement Indoor Positioning System(IPS).The paper includes comparison of various real world scenarios that are using these technologies for indoor positioning.It compares these examples to find their pros and cons respectively.So that it will motivate reader to so more research in this field and apply this knowledge according to their own needs.*

Keywords- Indoor Positioning System, Wi-Fi, Trilateration, Wi-Fi Fingerprinting, RSSI, KNN.

I. INTRODUCTION

In our every day lives location has been an important factor.A Positioning System enables mobile devices to get their Accurate location and provide other locating based facilities such as tracking, monitoring, navigating.

Currently Global Positioning System(GPS) is mainly most widely used user localization technique.In most Smart phones there are transceiver found that can be used to send and receive GPS signals.These signals are used to determine users position through algorithms on Global Positioning System signals.

Some of the major advantages of Global Positioning Sys-tem(GPS) in terms of technology are Accuracy, Operatability, Versatility, Availability, and Reliability. This is because Global Positioning System (GPS) is dependent in signals received from at least 4 satellite.thus Global Positioning System is regraded as best general purpose navigation and localization tool in modern world. Global Positioning System is mainly used for outdoor localization.In closed environment. GPS signals from satellite are weak as it is blocked by the buildings structure itself. It is also effected largely by vast amount of human movement.Equipment's and Devices transmitting electromagnetic waves create an interference with the GPS signals and decreases its accuracy and efficiency.

To summarize the above discussion on Global Positioning System, the constant changes and type of obstacles limit the capabilities of Global positioning System(GPS).

This is where the indoor Positioning System Comes in picture.In recent years several indoor Positioning Systems have been proposed to overcome the drawbacks of the Global Positioning System. These system use various techniques and technologies and algorithms but none of these system have been proven to be effective in all cases. Therefore effective Solution does not exists that can solve all of these problems perfectly in a new user environment and with the preexisting constraints.

II. MOTIVATION

This paper aims to provide an overview on the most popular technologies and techniques.and gives a short survey on existing Indoor Positioning System in different user require-ments and scenarios.The work presented in the paper focuses on find the most efficient system according to the specific requirements.

III. TECHNOLOGIES FOR INDOOR POSITIONING SYSTEM

There are various technologies have been proposed to implement Indoor Positioning System. This section represents pros and cons of each of these technologies.

A. Vision

This technology is based on processing video streams.Video based Indoor Positioning System is implemented by either fixed camera system or mobile camera system.

In fixed camera system the infrastructure is under the surveillance of multiple static and dynamic cameras which captures the multiple images of the moving entities.by using position of the camera and the processing of images,the entity gets localized. In mobile camera system the camera is with entity itself. hence the captured images,provides the landmarks in known position and depending on the landmarks in environments localization can be performed.

Pros:

Accuracy of this technology varies between 10 6 and 10 1 which is good as compared to other technologies. [1]

Cons:

Implementation of the system will require high cost. coverage is dependent on the quality of camera. complexity of the system is high.

B. RFID

Radio Frequency Identification (RFID) is an emerging technology that has a great potential for quick responsive system.the ability to identify,trace and track information makes RFID an impressive technology.

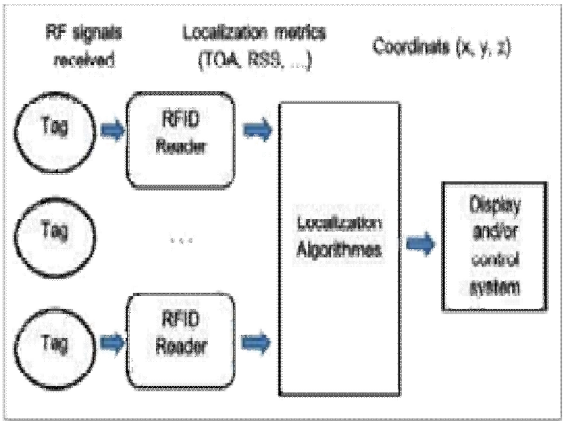

Fig. 1. IPS using RFID

for implementation of IPS using RFID ,there is involvement of RFID tags, RFID reader (reader contains multiple RFID reader antenna) RFID reader is equipped with the moving entity and the tags are distributed in an environment.

reader detects RFID tags with two input ranges i.e. first and last of RFID tags the Position of moving entity is estimate by intersection of two input ranges.

Pros:

Complexity of the system is low due to flexibility of the hardware components. cost is low as only one reader is required.

Cons:

Coverage of the system implements through RFID is less.Accuracy of the system is less when the difference between 2 tags is more. reader has less ability when reading of multiple tags at the same time. liquids are responsible for absorption of the RF waves which degrades the performance of RFID system. [1]

C. Infrared

Infrared radiation (IR) is a commonly wireless technology used to localize objects or moving entities. It is one of the most common services voice localization in Indoor. Indoor Positioning System with IR consists of infrared receiver and transmitter placed in specific positions of the infrastructure.

Emitter transmits IR waves which are received by the receiver after obstructed by the objects. receivers communicates to the algorithm used for localization that calculates the position based on the distance and angle between the objects and the receiver. [1]

Pros:

IR ranging are currently employed in Indoor environments because of low cost,less space Occupancy and low power consumption and nominal ranging.

Cons:

coverage of the IR system is less due to range of waves.accuracy of the system is deprecated by the obstruction of other waves than infrared. radiation signals are obstructed and interfered by other waves decreasing the efficiency.

D. Bluetooth Beacons

Bluetooth beacons have been really popular since 2013.Ap-ple exclusively relies on ibeacons for indoor positioning sys-tem(IPS) as Apple devices can't use wifi to determine their position.Beacons are placed at several positions in the building and via Bluetooth they send signals to mobile devices so in this way it is possible to determine their position continuously and transmit it to the indoor positioning system(IPS).

Beacons covers approximately 30 m distance inside the buildings [2].The number of beacons needed in a building depends on the size of the area and the required accuracy. Beacons are operated with batteries and so they are easy to install.if Beacons are connected to the power networks that makes its installation more complicated.

This technology offers significant advantage in the buildings that do not have pre-installed wifi infrastructure.There is requirement of a new installation of such beacons stations so that the existing building will become a navigation compatible system.

The use of Bluetooth technology within beacons permits them to use features of Bluetooth such as its lighter stan-dard,ubiquity,operates within 2.4 ghz industrial band.

Pros:

It is simply a better system for the infrastructure without wireless structures as well as gives best results for the small area when cost factor is considered.

It could be accurate about 2 to 3 m with a delay of about 20s only,as well as Bluetooth localization suffers from complex and changing environments. [2]

Cons:

Cost requirements held critical when number of beacons increases as the area of infrastructure is large,then the requirement of beacons is large in quantity.

In each location finding,it runs device discovery proce-dure,due to this power consumption will increases and results will be not much faster i.e. localization latency will increases.

E. Wi-Fi

This is the most widely used technology because most of the buildings are preinstalled with the wireless infras-tructure,which makes the system cost effective.Most smart phones are inbuilt with wifi adapter for connecting to wireless networks.

The Standard protocol of wifi is 802.11 which was in-troduced by Institute of Electrical and Electronic Engi-neering(IEEE) and it is used in wireless local area net-works(WLAN).Wlan infrastructure is widespread in many indoor systems hence this approach is widely used for Indoor Positioning System(IPS).

Received Signal Strength(RSS) is the most well known WLAN localization technique due its easy extraction in 802.11 networks and its ability to run on the WLAN hardware.Time of Arrival(ToA),Angle of Arrival(AoA) are less common to WLAN based positioning system since angle and time mea-surements are complex.

WLAN scanning finds available networks for connec-tion,typically scanning can be performed at low rate since the set of available networks changes slowly. when the device aims to estimate its own position while acquiring WLAN signals,the RSS measurements are needed from the available Ap's in order to minimize positioning error.

RSS in the considered environment are used to build the maps using wifi fingerprinting approach.An offline RSS fin-gerprinting of the environment is compared with an online RSS measurements to estimate the location of a user.

Indoor localization techniques which are based on mapping of label data exploits RSS to determine the location by reverse function which uses RSS fingerprinting resulting in coarse measurement as well as result.

This methods involve a calibration step where labelled data are collected before the system operation while Wi-Fi based indoor positioning is attracting the need for a significant effort in pre-deployment of an infrastructure is a key challenge but nowadays most of the environment are built with wireless Infrastructures.

Pros:

The system Built with Wi-Fi develops a major advantage of cost effectiveness and no setup for any power con-sumption.

Accuracy of Wi-Fi technology is between 20 to 40m but it can be improved with dense router deployment or just arrangements of Wi-Fi infrastructure. [2]

Another important advantage of using Wi-Fi technology is that mobile devices uses very low power for Wi-Fi adapters hence it consumes very low power sometimes the static environment can a attenuate the Wi-Fi signal but it holds good within wall as compared to other Technologies.

Coverage of the system implemented through Wi-Fi technology is more than any other Technology as it has greater bandwidth

IV. TECHNIQUES USED IN INDOOR POSITIONING SYSTEMS

There are various techniques have been proposed to imple-ment Indoor Positioning System. This section elaborates on each of these techniques.

A. Trilateration

Trilateration approach works well with the WLAN posi-tioning system. Trilateration is one of the most

localization techniques that can be used for user localization in Indoor environment.

Three or more base stations are required the coordinates of these base stations must be known. The base stations can also be called as access points which can be Wi-Fi routers placed inside the building. Already existing Wi-Fi AP's can be directly used in trilateration thus saving any extra money spent on the setup of additional architecture.

The mobile units receives signals from these Ap's.This is denoted as SS or received signal strength(RSS). This RSS can be used to find out the distance between access points and mobile units.

The trilateration approach consists of two phases:

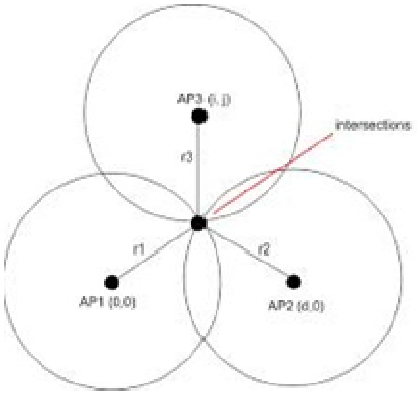

Fig. 2. Trilateration

First step is to convert received signal strength into distance between access point(AP) and mobile unit

Second step is using least square or other geometric method to compute the exact user location.

First step is the key to trilateration technique. This step is highly dependent on the environment and varies from place to place.

A solution to this is finding a relationship between RSS and separated distance by collecting samples data from known distances. This is named as learning procedure. The system shows accuracy of four to five meters. Accuracy is little worse than using fingerprinting technique. [3]

Pros :

No need for any pre-surveying of the building like in fingerprinting thus can be deployed directly to the environment

Takes less time to build and less effort required. Cons :

The problem with trilateration is obtaining distance from RSS accurately as the signal attenuates due to distance,loss of signal strength through walls and floors and multiple paths of signal propagation

Interference from other signals like microwave oven ,card less phones and Bluetooth based devices

Orientation of receivers antenna movement of the people inside building can affect RSS It is very difficult to build a effective and sufficiently accurate model of trilateration in the real world situation

B. Wi-Fi Fingerprinting

The most popular and widely used localization technique for positioning with wireless access points is based on mea-suring the intensity of the received signal and the method of "fingerprinting". [4]

The accuracy depends on the number of nearby access points whose positions have been entered into the database. The Wi-Fi hotspot database gets filled by correlating mobile device GPS location data with Wi-Fi hotspot MAC addresses. We need to divide the location into grid points.Collect the

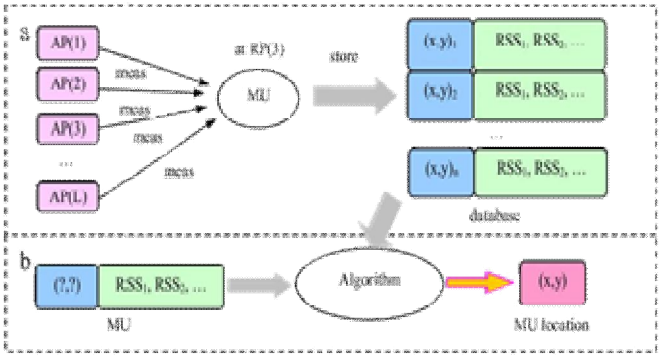

Fig. 3. Wi-Fi Fingerprinting [3]

RSS in each grid from to all the AP's. For example, if you are in position X and you have 3 AP, you are going to collect 3 measurements.Store the collected data in a database.

Find out the signal strength that is received from various AP's. The algorithm will determine the correspondence be-tween the Signal Strength in a database and the current Signal Strength, the most position (from DB) that matches with your Signal Strength, will be your position. Location fingerprinting consists of two phases: training and positioning. The goal of the training stage is to prepare a fingerprint database.

Locating a Mobile User at one Reference Point location, the SSs of all the APs are measured and is then recorded in the database. In the positioning stage, the Mobile user measures the RSS at a place where it wants to find the position. The Signal Strengths are compared with the stored RSS values in the database using an various matching algorithm. The outcome of the algorithm is the approximate location of the MU.

Pros:

The fingerprinting technique uses the existing hardware and architecture for its operation hence no extra resources are required for its effective working.

The accuracy of the fingerprinting technique is better than other techniques like trilateration.

Fingerprinting takes less time to localize the user i.e it is faster in operation.

Cons :

It requires more effort for doing fingerprinting before-hand.

A change in the structure of the fingerprinted building will cause all the fingerprinted database to be faulty and will be required to be done again.

V. ALGORITHMS USED IN WI-FI FINGERPRINTING

From the above discussion, it is clear that Wi-Fi fingerprint-ing is the better suited method for a place with existing Access points.This section deals with some of the algorithms that are used in matching the mobile user's data at the current location with the pre-existing Fingerprinted data to obtained the mobile users current location.

A. KNN

KNN stands for K Nearest Neighbours. KNN algorithm is one of the basic algorithms used to estimate the position of mobile user. [5]

In Wi-Fi fingerprinting technique KNN is really effec-tive.The received signal from various Access points are stored in a vector [S1; S2; S3::::Sn] for an unknown new location. While the database contains signal strength vectors for various reference points.

when k = 1 i.e. NN (Nearest Neighbour) Manhattan or Euclidean distance are calculated between SS vectors of new and unknown location and SS vectors of all the reference points stored in the database.So the nearest neighbour will be the reference point with the shortest distance and the location coordinates of the reference point is directly assigned to unknown current location of mobile user. But when K > 1 the K number of nearest reference points are considered , the average of the location coordinates of these K points is used as the coordinates of the unknown current location of user.

KWNN (K Weighted Nearest Neighbour) is a variation of KNN [5].It uses weighted average of the location coordinates of the K reference points. The inverse of the signal distance is used as a weighing scheme i.e each coordinate is assigned a weight which is inverse to its actual distance from the user location before taking their averages.

The number of reference points(points where data is finger-printed i.e stored in the database) affects the accuracy of the KNN algorithm.The more the number of reference points the more the algorithm is accurate. But more number of reference points means more time and resources required to do the fingerprinting work.This will also lead to a huge amount of fingerprinted database which will make the application bulky and slower in operation.

If the number of RP's go over a certain limit it will affect the accuracy negatively due to increased density of RP's in small area resulting in confusion and distortion.

Selecting the value of k in KNN algorithm is always a crucial part of the performance of the algorithm.The value of K being too high or too low, will effect the accuracy and efficiency of the algorithm.The Research shows that the algorithm yields the best results when k = 3 or 4 [3] for a medium size building/campus.

B. DCCLA Algorithm

DCCLA (density based clustering combined localization algorithm) [6]. Indoor positioning system has been one of the most widely research areas in recent years. Related work in this section is focused mainly on the localization. There are various approaches and methods are

used to localize the position using Wi-Fi fingerprinting method.

One of the techniques or algorithm among them which uses extra sensors and hardware components, where it uses just mobile devices and Wi-Fi access points to localize the mobile phone indoors without requiring any prior labelling or work of pre-surveying.

DCCLA is an unsupervised fingerprinting building tech-nique. This DCCLA method will avoid the site surveying or pre-deployment process which was found in several supervised learning methods of fingerprint building techniques. Working of DCCLA is based on the fingerprinting data collected by gathering RSSIs from available wifi access points.

It uses the collection of Wi-Fi access points RSSIs in the background of users smart phone when the mobile data devices stays at location for a longer time than usual and method detect the Wi-Fi access points RSSIs whether they are similar or not.

It would result in high density distribution and creates Wi-Fi fingerprints based on information collected hence DCCLA a technique was built to create Wi-Fi fingerprints with none to a minimum amount of onsite surve.

Algorithm

Density-based Clustering Combined Localization Algorithm (DCCLA) [6]

1: Procedure DCCLA
2: Separate the collected RSSI points into data sets, each data set with a unique MAC address MACi.
3: Order each data set to form a list Li, with increasing RSSI values.
4: Label each RSSI points (Pik) on each list Li as unchecked
5: for each ordered Li do
6: while there exist an unchecked Pik do
7: Calculate the Neighbourhood density of Pik (p(Pik))
8: if (p(Pik) is smaller than MinPts then
9: Label Pik as checked
10: continue the while loop
11: else if Pik belongs to an existing cluster Co i then
12: Merge neighbourhood of Pik to Co i
13: else
14: Create a new cluster Cp i
15: Label Pik as checked

There are two phases to implement this algorithm the first phase is the learning phase of DCCLA where it will build fingerprints based on the users mobile devices RSSIs from each AP's.

A fingerprints are generated in the specific received signal strength pattern of Wi-Fi AP found near mobile device location it is generally based on the density of RSS signals collected over certain time period.

Fingerprint database is created at the flow from the all generated fingerprints .This fingerprint database is been taken into consideration for building a model.In second phase the model generated from the first phase is used by algorithm to enable indoor localization.

The matching algorithm will check the matching between Wi-Fi receiver and fingerprints in the database. The number of times the matching algorithm runs to check for successful matches. The best match fingerprint is then the prediction of location by an algorithm.

The advantage of DCCLA is that it is more cost effective as no predeployment process or site survey is necessary

and used clustering for building Wi-Fi fingerprinting which is more informative instead of list of calibrations. However battery consumption of devices by using DCCLA is more as always scans for available RSSIs from AP's. Although it is unsupervised learning model has less accuracy as compared to the supervised fingerprinting technique in which the model is build already.

The model generation takes place on the fly hence the fingerprint database will change always according to the time period of an user. This algorithm can be improved to higher accuracy and techniques of building the model of fingerprinting database.

VI. CONCLUSION

The Indoor Positioning System is still under research. No fixed Solutions are available that will be effective in all the infrastructure and that will satisfy all the user re-quirements.Therefore a deep study of the available technolo-gies and techniques is required before selecting the proper one.The choice of the suitable technology depends on user requirements in terms of usability, accuracy, cost effectiveness, robustness, coverage area and so on. This paper provides a brief comparison between various existing technologies for implementing Indoor Positioning

System(IPS).This will be a starting point for further ideas and future research in this field.

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