Target Localization in Indoor Environment using Channel Response of WLAN

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Abstract

Indoor positioning systems have received increasing attention for supporting location-based services in indoor environments. Indoor localization technologies address the inadequacy of global positioning system inside a closed environment, like buildings. GPS does not perform well in urban canyons, close to walls, buildings, trees, indoors, and in underground environments as the signal from the GPS satellites is too weak to come across most buildings thus making GPS ineffective for indoor localization Although there are many radio based technologies that can be used for indoor positioning, Wi-Fi-based indoor localization has been attractive due to its open access and no overhead cost properties. Received Signal Strength Indicator (RSSI) has been adopted in vast indoor localization systems. However, it suffers from dramatic performance degradation in complex situations due to multipath fading and temporal dynamics. The distance estimation based on received signal strength indicator (RSSI) is easily affected by the temporal and spatial variance due to the multipath effect, which contributes to most of the estimation errors in current systems. Channel state information is detail Channel response at subcarrier level. CSI explore the frequency diversity of the subcarriers in orthogonal frequency division multiplexing systems. A novel approach is proposed to utilize Chanel state information to build propagation model and a fingerprinting system at the receiver.
Keywords- GPS, Localization, OFDM, RSSI, Wi-Fi

I. INTRODUCTION

Indoor positioning systems have gained popularity for supporting location-based services in indoor environments, because though the GPS system will give location info for outside environments GPS cannot provide correct positioning estimations for indoor use [1]. Thus, Indoor Position System is needed to support location-based services once the Personal Network is found in indoor space. The goal of the indoor positioning system was to develop a system that identifies position of a user in closed environment [2].

Such positioning system in indoor environment help clients explore in a shopping center, keeping in mind the end goal to discover particular stores or even shelves. Other clients for the framework would incorporate organizations keen on helping individuals explore to the right shelf in a distribution center. Indoor Positioning Systems (IPS) has led to expanded proficiency in numerous sorts of associations and commercial enterprises, and more organizations grasp the new opportunities and usefulness found in an IPS. IPS has numerous potential usages, and is for example utilized as a part of logistics, health awareness, resource tracking, crisis administrations, staff/guest distinguishing, security, etc. Keeping in mind the end goal to address the client's issues and offer versatile and helpful individual administrations, the area data of the persons and their gadgets at better places, for example, home, office, and so forth., can be given by the IPSs to any applications in Personal Networks. Above application rely on indoor localization. Fulfillment of required effectiveness, security produces several challenges and strict requirements.

II. WI-FI BASED INDOOR POSITIONING

Infrared radiation (IR) positioning systems, Radio frequency identification (RFID) based system, Bluetooth, Ultra wideband (UWB), FM radio based system, The ZigBee technology are all emerging area in Indoor positioning system [3].

though there are numerous advancements which can be utilized for indoor positioning, already installed Wi-Fi network inside any building can provide a platform for implementing indoor positioning without any added cost[3],[4],[5]. Wi-Fi based indoor localization has been alluring due to its open access and minimal cost properties. Typical Indoor positioning system using Wi- Fi Network typically uses received signal strength indicator for estimation. However, the distance estimation based on received signal strength indicator (RSSI) is easily influenced by the temporal and spatial variance due to the multipath

environment that contributes most of the estimation errors in present system. This work, analyze this effect across the physical layer and account for the undesirable RSSI readings being reported. It explores the frequency diversity of the subcarriers in orthogonal frequency division multiplexing systems and proposes another methodology that uses subcarrier level information for position detection. Channel state information (CSI) at subcarrier level is used to build a propagation model.[6] I'm using off the self-802.11 NICs to realize indoor position system and I'm also intended to evaluate its performance in different typical indoor scenarios. The Primary observation shows that the accuracy and latency of distance calculation can be significantly enhanced by using CSI.

A. MIMO – OFDM

MIMO system employs multiple transmitter and receiver antennas for delivering parallel data streams, as illustrated in Figure 1.

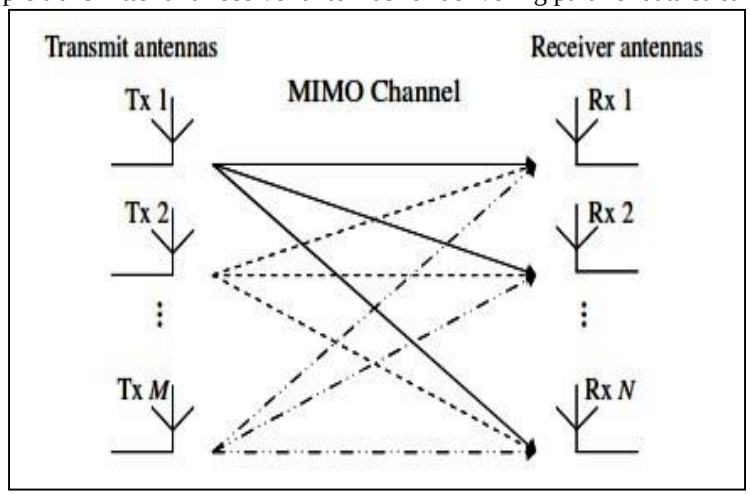

Fig. 1: Schematic of MIMO system

The information is transmitted through different paths; a MIMO system is capable of exploiting both transmitter and receiver diversity, hence maintaining reliable communications. Furthermore, with the advent of multiple antennas, it becomes possible to jointly process/combine the multi-antenna signals and thus improves the system's integrity and/or throughput. Briefly compared to Single-Input Single-Output (SISO) systems, the two most significant advantages of MIMO systems are:

- A significant increase of both the system's capacity and spectral efficiency. The capacity of a wireless link increases linearly with the minimum of the number of transmitter or the receiver antennas. The data rate can be increased by spatial multiplexing without consuming more frequency resources and without increasing the total transmit power.
- Dramatic reduction of the effects of fading due to the increased diversity. This is particularly beneficial, when the different channels fade independently.

The quality of a wireless link can be described by three basic parameters, namely the transmission rate, the transmission range and the transmission reliability. Conventionally, the transmission rate may be increased by reducing the transmission range and reliability. By contrast, the transmission range may be extended at the cost of a lower transmission rate and reliability, while the transmission reliability may be improved by reducing the transmission rate and range. However, with the advent of MIMO assisted OFDM systems, the above-mentioned three parameters may be simultaneously improved. Initial field tests of broadband wireless MIMO-OFDM communication systems have shown that an increased capacity, coverage and reliability is achievable with the aid of MIMO techniques. [7]

MIMO-OFDM has formed the foundation of all candidate standards proposed for IEEE 802.11n.

B. Localization

Today, most application requirements are locating or real-time tracking of physical belongings inside buildings accurately; thus, the demand for indoor localization services has become a key prerequisite in some markets. Moreover, indoor localization technologies address the inadequacy of global positioning system inside a closed environment, like buildings.

Location based services (LBSs) are a significant permissive technology and becoming a vital part of life. In this era, especially in wireless communication networks, LBS broadly exist from the short-range communication to the long-range telecommunication networks. LBS refer to the applications that depend on a user's location to provide services in various categories including navigation, tracking, healthcare, and billing. However, its demand is increasing with new ideas with the advances in the mobile phone market. So, the positioning technologies have a major influence on the performance, reliability, and privacy of LBSs, systems, and applications. Position system is a system arranged in such a way to find or estimate the location of an object.

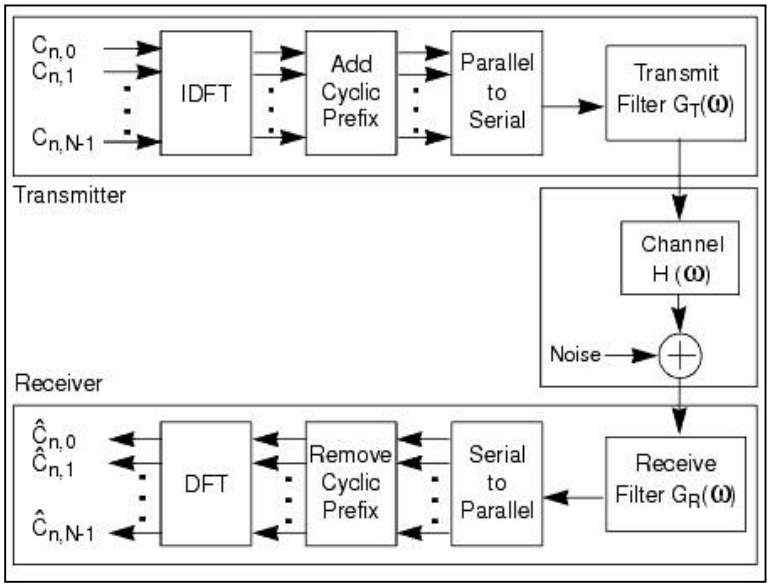

Fig. 2: FFT based OFDM schematic

C. Location Detection Techniques and Location Algorithms

Several different methods are used for location techniques and algorithms in wireless based localization. Location detection techniques can be divided into three general categories: proximity, triangulation and scene analysis as shown in Figure 3.

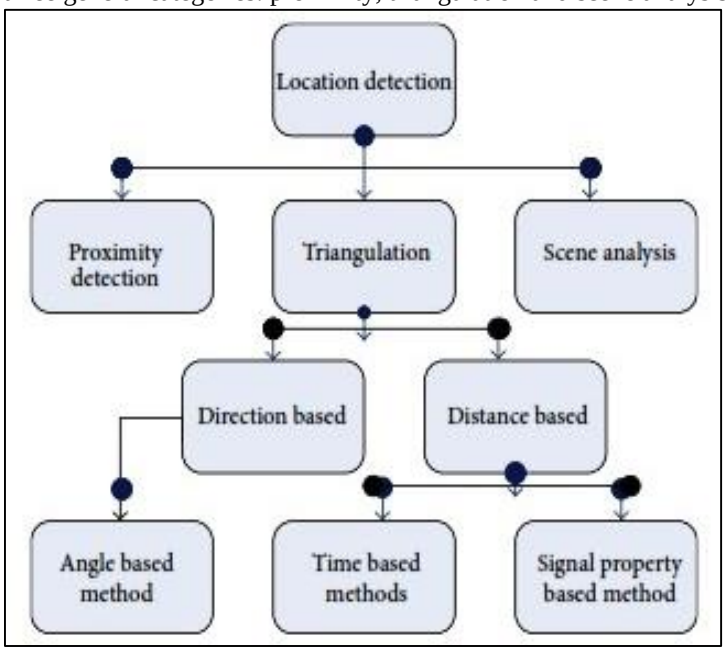

Fig. 3: Location detection classification

1) Proximity Detection (Connectivity Based Positioning)

Proximity detection or connectivity based is one of the simplest positioning methods to implement. It provides symbolic relative location information. The position of mobile client is determined by cell of origin (CoO) method with known position and limited range. When more than one beacon detects the mobile target, it simply forwards the position nearest where the strongest signal is received.

2) Triangulation

Triangulation uses the geometric properties of triangles to determine the target location. It has two derivations: late ration and angulation. Techniques based on the measurement of the propagation-time system (e.g., TOA, RTOF, and TDOA) and RSS-based and received signal phase methods are called late ration technique. The AOA estimation technique is called an angulation technique.

III. POSITION SYSTEMS

This section presents a review of most prominent state-of the- art wireless positioning systems as shown in Figure 4. Main focus is put on the radio based systems especially in wireless local area network (WLAN) positioning. As people spend most of their time in a closed environment (indoors), GPS is not well suited for indoor positioning tracking. [5]

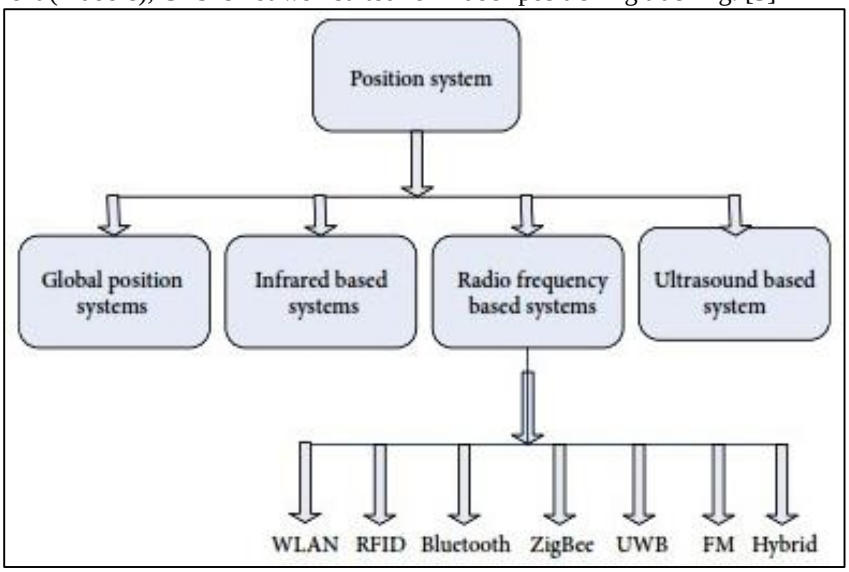

Fig. 4: Radio based Positioning system

Infrared radiation (IR) positioning systems are one of the most common positioning systems that use wireless technology. The spectral region of infrared has been used in various ways for detection or tracking of objects or persons and available in various wired and wireless devices such as mobile phone, PDAs, and TV. Most IR based wireless devices uses line-of-sight (LOS) communication mode between transmitter and receiver without interference from strong light sources. The main advantage of using IR based system devices is being small, lightweight, and easy to carry out. The IR systems undertake an indoor positioning determination in a precise way. Besides these, IR based indoor positioning systems have some disadvantages like security and privacy issues. IR signals have some limitations for location determination, like interference from fluorescent light and sunlight. Beside this, the IR based indoor system has expensive system hardware and maintenance cost.

Radio frequency technologies are commonly used in location position systems because of some advantages; for example, radio waves can penetrate through obstacles like building walls and human bodies easily. Due to this, the positioning system in RF based has a larger coverage area and needs less hardware comparing to other systems. In addition, RF based technologies are further divided into narrow band based technologies (RFID, Bluetooth, WLAN, and FM) and wide band based technologies (UWB). RADAR by Microsoft Research was the first RF based technique for location determination and user tracking. Radio frequency identification (RFID) has been recognized as the next promising technology in serving the positioning system for locating objects or people.

RFID enables a one way wireless communication using a noncontact and advanced automatic identification technology that uses radio signals that put an RFID tag on people or objects, for the purpose of automatic identification, tracking, and management. Tracking the movements of objects in RFID is done through a network of radio enabled scanning devices over a distance of several meters. RFID technology is used in a wide range of applications including people, automobile assembly industry, ware house management, supply chain network, and assets without the need of line of sight contact.

Bluetooth is a wireless standard for wireless personal area networks (WPANs). Almost every Wi-Fi enabled mobile device, such as mobile phone or computer, also has an embedded Bluetooth module. Bluetooth operates in the 2.4GHz ISM band. The benefit of using Bluetooth for exchanging information between devices is that this technology is of high security, low cost, low power, and small size. Each Bluetooth tag has a unique ID, which can be used for locating the Bluetooth tag. One of the drawbacks of using Bluetooth technology in localization is that, in each location finding, it runs the device discovery procedure; due to this, it significantly increases the localization latency (10–30 s) and power consumption as well. That is why Bluetooth device has latency unsuitable for real time positioning applications.

Ultra wideband (UWB) is a radio technology for short range, high-bandwidth communication holding the properties of strong multipath resistance. Widespread use of UWB in a variety of localization applications requiring higher accuracy 20–30 cm than achievable through conventional wireless technologies. A typical UWB setup structures stimulus radio wave generator and receivers which capture the propagated and scattered wave. Moreover, UWB hardware is expensive, making it costly for wide-scale use.

The FM radio based system is popular through the ages. It is widely available across the globe especially in most households and in cars. FM radio uses the frequency-division multiple access (FDMA) approach which splits the band into a

number of separate frequency channels that are used by stations. FM band ranges and channel separation distances vary in different regions. There are only a few works dedicated to FM radio based positioning.

The ZigBee technology is an emerging wireless technology standard which provides solution for short and medium range communications due to its numerous benefits. It is mainly designed for applications which require low-power consumption but do not require large data throughput. The signal range coverage of a ZigBee in indoor environments is typically 20m to 30 m. Distance calculation between two ZigBee nodes is usually carried out from RSSI values. ZigBee is open to interference from wide range of signal types using the same frequency which can disrupt radio communication because it operates in the unlicensed ISM bands.

Hybrid positioning systems are defined as systems for determining the location of a mobile client combining several different positioning technologies. Many location technologies are used to estimate the position of mobile client in a space or grid, based on some mathematical models. The local positioning systems fail to work outdoors, whereas the GPS based positioning systems do not work inside buildings due to the absence of line of sight to the satellites. So, there is a need for positioning systems that can work both indoors and outdoors, and hence, the concept of hybrid positioning systems is used.

Ultrasound system is a technology based on the nature of bats and operates in the low frequency band compared to the other two signaling technologies. The ultrasound signals are used to estimate the position of the emitter tags from the receivers. Ultrasound is unable to penetrate walls but reflects off most of the indoor obstructions. However, it has a lower level of accuracy (in centimeters) and suffers a lot of interference from reflected ultrasound signals propagated around by other sources such as the collision of metals. Some recent research work was carried out under ultrasound based indoor localization.

A. Wi-Fi-Based Indoor Localization

One of the advantages of using Wi-Fi Positioning Systems is to locate the position of almost every Wi-Fi compatible device without installing extra software or manipulating the hardware. Beside this, in WLAN, line of sight is not required. Due to this advantage, Wi-Fi positioning systems have become the most widespread approach for indoor localization. Most positioning systems based on WLAN (Wi-Fi) are available as commercial products as prototypes based on measurements on the received signal strength (RSS)[12]. Wi-Fi based positioning systems have several advantages. Firstly in terms of cost effect, WLAN infrastructures implementation of position algorithms does not need any additional hardware as network interface cards (NICs) measure signal strength values from all wireless access points in range of the receiver. Therefore, signals needed for positioning can be obtained directly from NICs available on most computing devices. Due to the ubiquity of WLANs, this mode of positioning provides a particularly cost-effective solution for offering LBS in commercial and residential indoor environments. Secondly, WLAN positioning systems offer scalability in two respects: first, no costly requirement of infrastructure and hardware and second the number of mobile devices subscribing to positioning services. Beside this, there are also certain WLAN limitations: signal attenuation of the static environment like wall, movement of furniture and doors. [13]

B. Fingerprinting Based Indoor Localization

Most indoor localization approaches adopted fingerprint matching as the basic scheme of location determination. The main theme is to collect features of the scene (fingerprint) from the surrounding signatures at every location in the areas of interest and then build a fingerprint database. The location of an object is then determined by matching online measurement with the closed location against the database.

This method does not require specialized hardware in either the mobile device or the receiving end nor is no time synchronization necessary between the stations. It may be implemented totally in software which can reduce complexity and cost significantly compared to angulation or purely time based late ration systems.

The location fingerprinting also called a fingerprinting method consists of two phases. Phase 1 is the so-called calibration phase, offline phase, or training phase, and phase 2 is the localization phase or online phase. In the offline phase, maps for fingerprinting are set up either empirically in measurement operations or computed analytically (signal strength reference values (anchor point) can be computed using a signal propagation model). In the first phase, a creation of radio maps for site survey where the positioning is supposed to work must be recorded. Basically, radio map is a database of spots at predefined points (coordinates) coupled with various radio signal characteristics, for example, RSS, signal angles, or propagation time called signal fingerprints. Step by step, for every fingerprint, there must be a measurement that includes the information about all stations and their received signal strength (RSS). When the localization system is operational, online phase, the mobile station measures signal properties at unknown spot. Then, the current measured signal strength values are compared for the best agreement with a database (radio map). The major drawback of the fingerprinting approach is the laborious and time-consuming calibration process. Furthermore, adding signal stations would challenge the ease of setup in fingerprinting.[8]

IV. IMPLEMENTATION

Here we have used 802.11n measurement and experimentation platform that include Intel 5300 Wi-Fi link along with CSI tool. The CSI Tool is built on the Intel Wi-Fi Wireless Link 5300 802.11n MIMO radios, using a custom modified firmware and open source Linux wireless drivers[6].

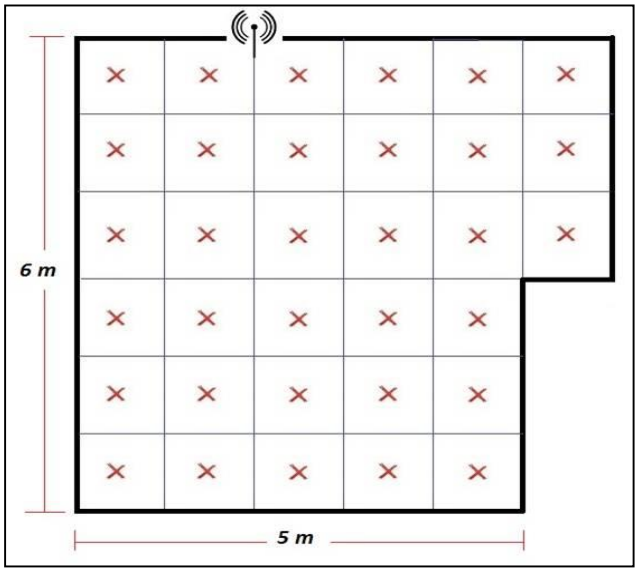

Fig. 1: Test Locations for Fingerprint Database

As shown in Fig.-1, the total test area can be divided into several locations and fingerprint database is collected for that locations.

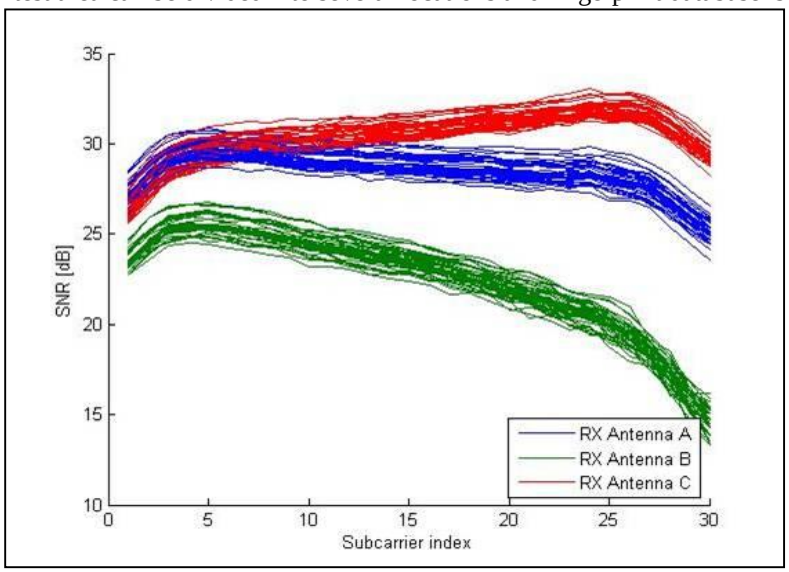

Fig. 2: CSI magnitude plot for 3 Rx antennas

Fig.-2 Shows the plot of 1*3 MIMO link that represent absolute CSI readings against subcarrier value on Y axis. As visible from figure, CSI magnitudes are highly regular for particular reading compared to RSSI variation.

C. Location Specific Pattern

The signals received at any location in indoor environment will be multipath signal by nature. The received multipath signal for different location will possess different magnitude and phase characteristics. When collected for sufficient amount of time the received channel response for each subcarrier include valuable information for fingerprinting of that location. Figure shows the stable pattern of CSI magnitude over several test locations. Shape of plot and number of magnitude clusters are unique and depend on specific location.

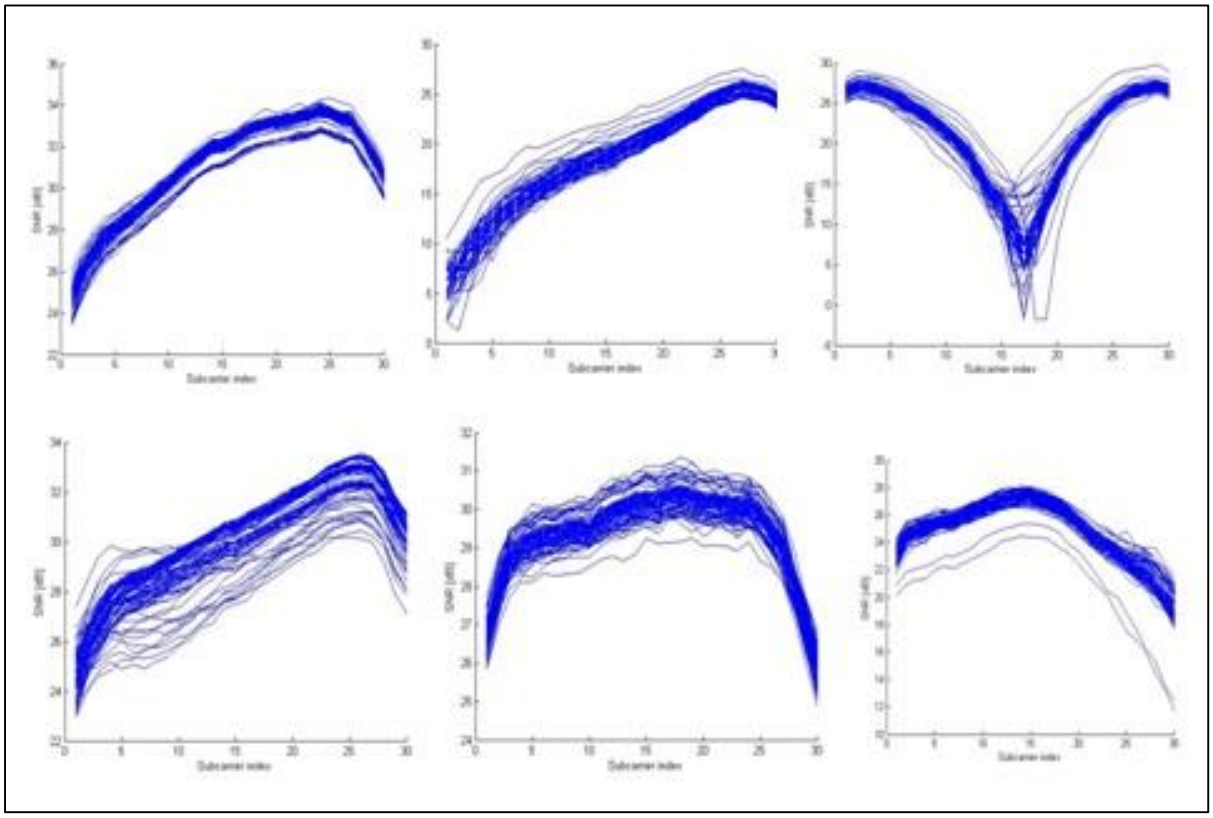

Fig. 3: CSI plot for Different Locations

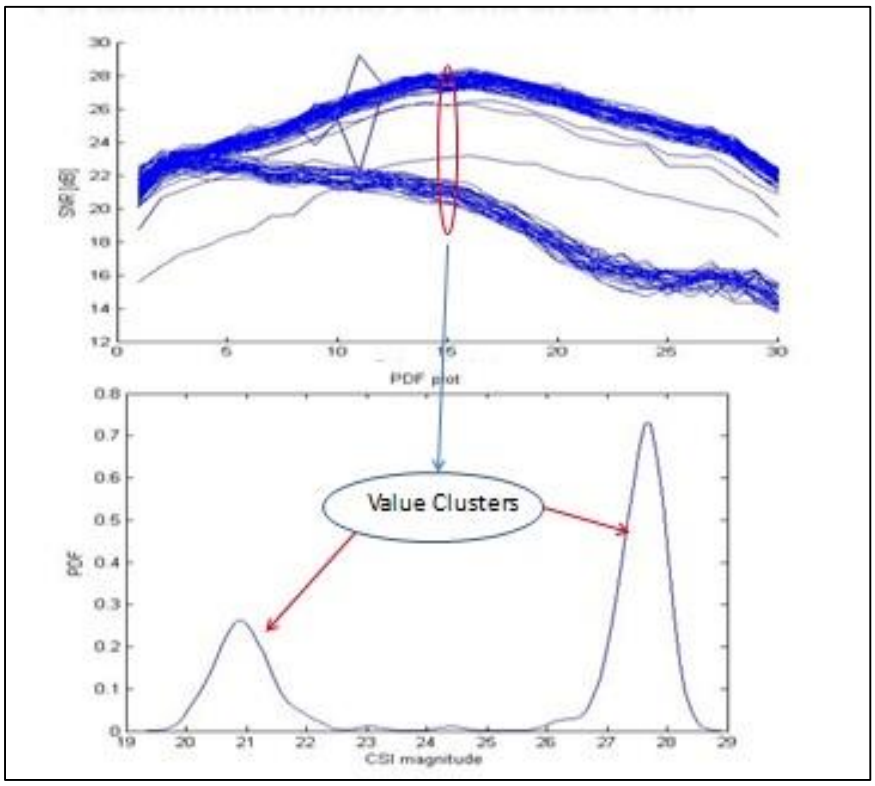

Fig. 4: CSI magnitude cluster for single subcarrier

Fig.4 shows the CSI plot for any single location. It clearly indicates that there is more than one cluster available for a different location. In such scenario, we call collect the desired attributes for the no. of groups available.

D. CSI Clustering

The CSI magnitude plot is dependent on location. Magnitude clusters also vary as per different locations. We used K-means algorithm. K-means clustering will partition the given data into defined number of clusters. The derived clusters are based on their nearest mean value.

E. Classification Algorithm

The classification module finds the minimum distance between fingerprint database and the presently selected CSI values. Based on it, it will identify the probable candidate locations. Then estimate the most likely location as the desired location.

F. Limitation

We selected 2 dimensional spaces as our test environment. The practical scenario will require 3 dimensional reading for locating the target. Due to complexity of fingerprinting based positioning 3 dimensional data collection will consume lot of time.

The pattern of the multipath CSI traces might get changed due to modification in interior environment, particularly the metallic structure. So the revision of CSI database is needed at regular interval.

V. CONCLUSION

Localization is one of the most appealing applications and becomes increasingly common in our daily life. Importance of Indoor localization and limitation of GPS is highlighted. Overview of various radio based localization techniques as discussed in literature review indicates that Wi-Fi based localization techniques has no cost overhead, has flexibility and have adequate speed and accuracy. RSSI-based localization scheme is used widely to provide location based services inside indoor environments. However primary limitation is that the RSSI is very fickle indicator. It depends on environment; it is device specific, and produces large temporal variation. Channel response of multipath component of received signal generate a stable pattern at every location is deduced. This location specific signal clustering is utilized to implement meter scale level indoor positioning.

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