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Device-free Localization Technique for Indoor Detection and Tracking of Human Body: A Survey

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Abstract

The extensive usages of WLANs and mobile devices have increased the interest in Indoor localization systems for wireless environments. In the context of wireless-based localization system, researchers have always focused on device-based localization system, in which tracked entities must have a device attached. This practice for many years developed localization systems like Global Positioning System; Radio Frequency based system, Ultrasonic bases system and Infrared base systems. These all location based systems need a device to be attached with tracked entity, in order to run part of localization algorithm. Thus, all these systems are called as active device-based location systems. Recently a new concept device-free localization system is introduced; this system can detect and track any entity without carrying any radio device or participating actively in the localization process. A human body is detected in the device-free localization system by observing the changes in the received signal strength of WLAN environment. This paper presents a comprehensive survey of various techniques of the device-free localization system.

Keywords: Indoor Localization; Device-free Localization

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1. Introduction

The widespread growths of localization systems and fast advancements in the networks of communication have motivated the extensive research interest in the location determination area. At present estimating the possible location of any entity has become the crucial component of WLAN environment. Approximating the location is useful for various applications like monitoring patients in hospital, estimating the location of assets, tour guides, conference guides, shopping guides and information, games, network access based on the user's location and security (Vorst, Sommer, Hoene, & Carle 2008). The Global Positioning System (GPS) is famous outdoor location estimation used worldwide. GPS was first time used for military application (Youssef & Mah, 2007). Due to low cost for implementing the number of devices using GPS technology is increasing every year. Although GPS has become the popular technology for tracking and navigation purposes, it has some limitations as well. For example, no functionality in indoor environments and requirement of attached device with user at all times, in cities with tallest buildings, or between mountains because of the requirement of Line-of-Sight (LoS) to communicate satellites. Therefore, there is a dire need for an accurate indoor location-based system. For these reasons, device-free localization (DfL) system has recently attracted the attention of the research community (Patwari & Wilson, 2010).

The WLAN Device-free localization concept was first time introduced in (Seifeldim & Youssef, 2010), and it takes advantage of extensive deployment of Wi-Fi network everywhere. The DfL can detect human body in indoor environment by analyzing how a human body changes the pattern of received signal strength without wearing any device. This concept is applied both for detection and tracking of human body. In comparison to wired security and surveillance systems, WSN reduce both cost and installation time, and can be easily reinstalled at any other area of interest if required. On the other hand, low cost of unit leads to deploy many nodes to cover a larger area.

Figure 1 depicts the different components of DfL system. A dfL system consists of access points (APs)as the signal transmitter, monitoring points (MPs) such as personal computer or a laptop and an application server (AS) to initiate actions as required and process the data.

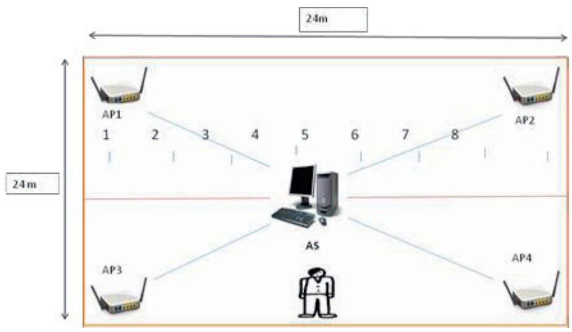

Figure 1. System components of DfL

This paper focuses on the survey of various device free localization techniques and systems. This work provides the key features of recent developments in the device-free location based system. The paper also highlights the challenges of this area of research.

2. Device-free Localization (DFL) System

A system used to detect, track and can identify any object or human body without any device attached as well as not actively participating in the localization process is called as Device-free localization (DfL) system. For intrusion detection, a DfL system uses WIFI network without the use of any additional hardware, and increases the smartness of any WiFi-enabled device. On the other hand, in a Dfl system the object to be tracked require no device to carry and participate actively in the localization prcess. The concept of DfL system works on the criteria that the presence and motion of human body changes the pattern of radio frequency signals. This change is specially observed in 2.4 GHz band which is required for various IEEE standards like 802.11b and 802.11g. The presence and movements of human body inside monitored area of Wireless sensor networks (WSNs) perform the task to extract the useful information from the changes in the received signal strength indicator (RSSI). In this type of system no extra hardware is required like cameras or any other sensors, however the node composing the network is considered as radio frequency (RF) sensors.

Various studies have identified that RSSI can be used to for the detection and tracking of an entity found in the monitored area of WSN network. (Shikoska, and Davchev, 2010) analyzed that RSSI can be used to detect the location of individual between two nodes of communication. In this work they show a correlation between the alerts of RSSI-based algorithm of intrusion detection and the crossing of line-of-sight (LoS) radio link. The observation made was validated by using a beam of light travelling from one node to the other and the RSSI-based algorithm was obtained by a high level of correlation between the light beam crossings. A moving person causes the shadowing and multipath fading of the radio signal was analyzed by the results of (Hightower, and Borriella, 2001).

By observing the variance in the RSSI, Wilson and Patwari in the attenuation field of network were able to approximate the location of individual around the multiple nodes (Zhang, Xia, Yang, Yao, and Zhao, 2010). The system is calibrated in static conditions first in their experiments i.e. when no object is found in their in the monitored area. The results of calibration phase at run-time are then used to get the difference in the RSSI measurements, and to obtain the location estimation Tikhonov regulation is applied. The work by (Zhou, and Pollard, 2006), to get the location estimation of an intruder, the attenuation field and the statistical attenuation model are used. Additionally, for tracking the movements of the person a kalman filter is used off-line for previously collected data. The nodes are installed around the house during the experiments. The tracking error is 1.03 m average. The lag introduced by the kalaman filter causes most of the error, but also by delay caused by collection and processing of RSSI measurements. The average tracking error is reduced to 0.45 m without these delays.

The work by (Yang & Chen, 2009) formulated the localization as a fingerprint-matching problem. The target's location was estimated by comparing the current link measurements with the trained database. While the method achieves reasonable performance, the training measurements increase exponentially with the number of wireless links and targets, and will be inaccurate with the change of the environment. Table 1 compares some DfL systems.

Various approaches such as location fingerprinting (scene analysis), triangulation, trilateration, hyperbolic lateration, proximity, and dead reckoning (Cook, Buckberry, Scowcroft, Mitchell, & Allen, 2005) were used in location sensing systems. The metrics used frequently for developing tracking systems are: Received Signal Strength Indicator (RSSI), Time of Arrival (TOA) / Time Difference of Arrival (TDOA), and Angle of Arrival (AOA) or Direction of Arrival (DOA). The work by

(Raghavan, Ananthapadmanaban, Sivamurugan, and Ravindran, 2010), DfL tracking is done through fingerprint matching. A passive radio map is constructed during the training phase by recording RSS measurements with a subject standing at pre-determined locations. During the testing phase, the subject appears in one of these locations, and the system can match the observed RSS readings to the RSS readings from one of the trained locations based upon minimum Euclidean distance. PC-DfP (Boukerche, Boliveira, Nakamura, & FLoureiro, 2007) shares the same philosophy with (Pellegrini, Persia, Volponi, & Marcone, 2011) and takes special care in the training phase to minimize the RF signal variation within short distances to mitigate the error caused by the multipath effect.

Table 1. DFL System Comparsion

System	Location Technologies	Positioning Algorithm	Accuracy/Precision	Complexity	Scalability /Space dimension	Cost
Through – Wall Motio Tracking (VRTI) (2006)	Passive RSSI, IEEE 802.15.4	Kalman Filter	0.45 m/NA	Medium High	Good/2D	Low
EasyLiving: Multi-camera Multi-person	Video Images	Video Processing Algorithms	Approx. 10cm/NA	Medium High	Good/2D	High
Device-free Passive Localization	WLAN, Passive RSSI, IEEE 802.11 a/b/g/n	Bayesian Inversion	Approx. 18 cm/NA	Moderate	Good/2D	Low
TileTrack	Capacitance between multiple floor tiles and receiving electrodes	Centroid of	14.3 cm- standing, 40.7 cm Walking/80% within 10 cm	Moderate	Poor	Low
AirBus	Differential air pressure	Feature Extraction Algorithms	68%-80%	Moderate	NA/NA	Low

The work in (Kuang & Shao, 2003) developed a novel fuzzy support vector machine for device-free localization. The fuzzy support vector machine is an integration of SVMs and fuzzy systems; therefore a fuzzy system can be extracted from an SVM. The simulation results show the reduced fuzzy system is easy to perform optimization and generates better results than pure SVM. An simulation result shows the correctness of pure SVMis 66.8% and the correctness of optimized fuzzy systems is 74.6%. The (Narzullaev, & Jung, 2008) assessed the exhibition of the Nuzzer framework in a manufacturing, rich in multipath, with a range of in the vicinity of 750 square meters. The effects show that the Nuzzer framework gives an average separation mistake of 6:74 meters, 2.1 times superior to an arbitrary estimator. The work by (Giovanni, Francesco, Andrea, & Michele, 2008) likewise put forth a system for distinguishing the gatecrashers dependent upon the change of the Rss. The proposed strategy can give 100% likelihood of location in commonplace situations. It works by building an aloof radio guide throughout a logged off stage, then utilizes an Euclidian separation based estimator to figure out the closest radio outline, as far as separation in the sign quality space, to the obscure area. Their work additionally displayed two post transforming procedures: the spatial and temporal averaging to further improve the correctness of the essential deterministic method.

Rasid (Priwgharm, & Chemtanomwong, 2011) utilizes non-parametric factual irregularity discovery procedures to furnish the identification ability. The Rasid framework additionally utilizes profile redesign methods to catch updates in the environment and to improve the discovery correctness. The framework was assessed in two diverse legitimate situations. Utilizing the same parameters for the two test bunks, the framework gave a faultless identification proficience arriving at no less than 0.93 in both test couches. Moreover, it demonstrates that the non-parametric methodology utilized by Rasid has significant preferences over a parametric methodology for the framework operation. The (Goldoni, Savioli, Risi, & Gamba, 2010) portrayed the Dfp framework's building design and indicated that the framework works with the ostensible Wifi supplies. Our effects show that the framework can locate development with high likelihood and flat false positive rate in regulated situations. Additionally, the framework can track the interloper's position to inside a couple of feet. The test effects are uncertain for verifying optimal Dfp framework configurations. Extra estimations are required both for this reason in the lifelong objective of arranging an economically deployable framework. The outcomes to date have built the confirmation of notion of the Dfp innovation.

This work in (Wang & Xiao, 2010) concentrates on manufacturing diverse situations for measuring Rssi, measuring the Rssi in each of these situations, applying the restriction calculation to the information gathered, and at last breaking down the confinement calculation correctness. Firstly, physical and intelligent topology of the system were planned and all supplies, incorporating APs, Wi-Fi, Catalyst 6509, Application server, and laptops were arranged to furnish a legitimate setup for estimation of Rssi. Also, Rssi was measured from portable computer and right to gain entrance focus point of view independently. At last, in situations with distinctive outer conditions, the gathered information were examined and their effect on the restriction exactness of the Euclidean Minimum Distance calculation was recorded.

The author (Luo, Brien, & Julien, , 2011) has focused on tracking mobile subjects using PC DfP. The argument given is that human mobility can actually introduce new opportunities for optimizing the localization accuracies in a real indoor environment. In a deployed indoor area, PC-DfP discretizes physical locations into cells, which simplifies the representation of the neighbor relationship among cells, given that the size of the cell is small enough to satisfy the required localization precision. Experimental results show better localization accuracy by carefully tuning the system parameter – the neighbor order. More study will be conducted to further improve the tracking performance and to track multiple subjects. The work by (Emery, & Denko, 2007) presented the design, implementation, and evaluation of the Nuzzer device-free passive localization system. The performance was evaluated both analytically and experimentally in two typical test beds rich in multipath. The results show that, for the first test bed, the Nuzzer system gives a median distance error of 1.82 meters, 3.7 times better than deterministic techniques and 7.7 times better than a random estimator. For the second test bed, the system gives a median distance error of 0.85m.

The authors (Liu, Gong, Zhou, & Wang, 2010) considered the performance of the Device-free Passive (DfP) detection system in a real environment. This work evaluated the performance of the system using two previously suggested algorithms: the moving average and the moving variance. It is shown that although those algorithms gave a 100% recall and precision in a controlled environment, their performance severely degrades when tested in a real environment. The work proposed another algorithm, the maximum likelihood estimator, as an alternative. The experimental results showed that the performance of the DfL system, in a real environment, was significantly improved using the proposed algorithm. The work by (Dong, & Jiancheng, 2009) proposed to perform joint learning for detecting intrusion when intruders do not carry any wireless devices (e.g., intrusion to corporate assets or people trapped in a fire building). The experimental results provide strong evidence of the feasibility of performing joint learning for passive intrusion detection. Moreover, the results show that our strategy of using collaborative efforts across multiple transmitter-receiver pairs can complement the detection function and maximize the detection power with a minimum false positive rate (zero percent). Finally, an interesting observation is that the collaborative detection strategy can also bring another dimension of knowledge of identifying problematic wireless devices, which report wrong signal readings. The authors (Jaegeol, Seunghwan, Kiyoung, & Jaehun, 2010) considered a DfP localization, built using a Wireless Sensor Network (WSN). The focus was on the possibility of using a deployed RSSI based WSN for detecting a human body in an indoor environment. The results showed that this is a viable solution when a wireless network infrastructure is not available. The accuracy and precision of the system are currently not very good due to the availability of only one Sunspot Development Kit.

The work in (Mahtab, Van, & Wee-Seng, 2010) displays another methodology for mechanism free indoor client limitation using Radio Tomographic Imaging and Passive Rfid. To accomplish this objective we portray the estimation attributes of a latent Rfid field in portion and propose an adjustable static weighting model. Distinctive field plans are looked at by demarcating the pixel connection thickness for the entire field and a Rfid based imaging methodology is exhibited. Test information is gotten from a sending dependent upon another field outline with Rfid transponders on hip tallness. The information is post prepared with the proposed methodology and the effects are introduced.

3. Challenges

There are three challenges in the deployment of a WSN for real-time detection and tracking of intrusion based on the processing of RSSI. Firstly, the transmission range and the successful delivery of packet is limited in typical indoor environment. The transmission range of IEEE 802.15.4 low-power radios in unobstructed condition can reach 70 m, while for highly obstructed environment the communication can be guaranteed up to 10m range (Elbatsh, Macas, & Samiento, 2010).

Secondly, the challenge is the unpredictability of the RSSI measurements collected by different nodes and asymmetries of existing links. The values of RSSI are increased and decreased because of the shadowing to line-of-sight crossings, the lasting variation of the RSSI measurement are because of the movements of a person causing multipath fading. If the nodes pairs located for example at 10 m apart when multipath components of the radio signals are spread spatially, makes the detection challenging as the intruder crossing the LoS causes a variation in the RSSI values.

Thirdly, another challenge is posed by the real-time requirement in delivering packets to the base station. The outages between the sensing devices, communication delays and the sink node influence the accurate capability of intrusion detection and tracking.

4. Conclusion

This paper focuses on the survey of various device free localization techniques and systems. Initially the background of device-based localization techniques is established. This work provides the key features of recent developments in the device-free location based system. The paper also highlights the challenges of this area of research. In spite of the lot of progress made in this field, there are various open issues that need to be resolved. These issues include projected tracking of human body between indoor and outdoor environment, problems of synchronization, noise and interference impact reducing as well as energy efficiency. Although various techniques previously developed have shown concern to these issues but those techniques have different limitations. Like high cost of whole system, deficiency of precision and computational overhead. In the future these issues are expected to be tackled by innovative research efforts.

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