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A Survey about Privacy and Security in Indoor Localization Systems

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ABSTRACT: Indoor localization has increased these days due to its mission and the wide range of potential services that can be used for these technologies. Various techniques have been developed and proposed to provide indoor location techniques to improve the services provided to users in many applications. The purpose of this paper is to provide a detailed overview of the latest modern technologies used in this field and to focus on the privacy and security of these technologies.

KEYWORDS: Indoor localization, Positioning techniques, localization privacy and security.

I. INTRODUCTION

Over the past decade, localization has gained significant attention, with researchers using indoor and outdoor technique. Indoor localization systems like FM, Wi-Fi, UWB, RFID, Philips Lighting, and Bluetooth. These technologies are crucial in various applications and play a significant role in our lives[1-4,6].

II. INDOOR LOCALIZATION.

An indoor localization system (ILS) is a system to locate people or objects inside a buildings using many techniques. Indoor localization classified as follows[5,7,8].

1. CLIENT BASED INDOOR LOCALIZATION

Client-based localization allows positioning on user devices without server connection, primarily suitable for indoor navigation in airports, museums, and hospitals. An application analyses signals from access points, detecting position without server connection.

2. SERVER BASED INDOOR LOCALIZATION

Server-based positioning uses Wi-Fi, tags, or beacons to send unique keys, which are then transmitted to a server for position calculation. This method is ideal for asset and personnel tracking, detecting medical instruments, vehicles, and goods in retail and retail settings.

Examples of some server-based indoor localization techniques shown in table (1).

No	Technology	Localization Technique	publication-year	Client	Server
1	WI-FI	RSSI	2016		✓
2	WI-FI	RSSI	2016		✓
3	WI-FI	RSSI	2015		✓
4	Wi-Fi	Lateration ,RSSI	2015	✓	
5	WI-FI	RSSI	2015		✓
6	WI-FI	RSSI	2015		✓
7	WI-FI	RSSI	2014		✓
8	Wi-Fi	RSSI	2014	✓	



9	WI-FI	RSSI	2014		✓
10	WI-FI	Fingerprint	2012	✓	
11	Wi-Fi	Fingerprint	2011	✓	
12	WI-FI	Rssi	2011		✓
13	WI-FI	Fingerprint	2010	✓	
14	Bluetooth	RSSI	2014		✓
15	Bluetooth	RSSI	2011	✓	
16	Bluetooth	Bluetooth	2014		✓
17	IBeacon	RSSI	2015		✓
18	FM	RSSi	2011	✓	
19	RFID	RSSI	2017		✓
20	VLC	LED	2014	✓	
21	Combined Wi-Fi + beacons(6)	RSSI	2016		✓
22	Combined Wi-Fi +beacons(17)	RSSI	2016		✓
23	Zigbee	RSSI	2013		✓

Table 1. Examples of some indoor localization techniques.

Indoor location locations can be small and easily equipped with additional infrastructure. Nowadays, many research projects are proposed in this area. Indoor localization can be used for many applications and differs in many aspects.

3. Wireless Technologies for Indoor Localization

- FM (Frequency Modulation) is widely used for regional radio broadcasts[10,11].
- Wi-Fi is one of the most widely used wireless technologies. It follows a series of standards in the IEEE 802.11. It uses two bands without a license: 2.4 GHz and 5 GHz. Most of the buildings such as shopping centers or super office building already deployed Wi-Fi hotspots that provide coverage of the entire building and network access point.
 - ZigBee is a specification based on IEEE 802.15.4 standard. It uses 868 MHz band in Europe, with high-data rate and require low-latency and low-energy consumption.
 - UWB (Ultra-Wide Band), is a radio technology that can use a very low energy level for short-range, high-bandwidth communications.
 - RFID Radio Frequency Identification is very simple technology. It consists of two parts: tag and reader. The reader uses radio-frequency electromagnetic field to read the data in the tag and get the identification of the object that tag attached to. The tag can either have battery or not which makes it an active tag or a passive tag.
 - Bluetooth is a personal area network standard with low-power wireless technology used transfer data and broadcast information between devices .Bluetooth is used for short distance communication such as earphones, mobile phones. Bluetooth concerns the power consumption, it uses a very low transmission power. Thus, the Bluetooth shorter than Wi-Fi and other wireless technology coverage. Hence, Bluetooth is not useful for localization for large area.
 - Philips Lighting
 - it is considered that the lighting has already been installed in all indoor spaces and it is more natural to create a system for internal positioning out of a lighting system, than to install a completely separate infrastructure. Philips IPS system



uses Philips VLC technology. With the help of VLC, each installation sends its unique ID to the user’s smart device and the system can accurately determine the user’s location. VLC is installed directly in the Philips LED luminaries and does not require additional installation, maintenance or power.

III. PERFORMANCE

The accomplishment of a given task measured against preset known standards accuracy , cost, coverage area and speed. The investigation of positioning products as “complete,” which contain all capabilities available in the category. The preference for complete-positioned products changes under different levels of many factors.

A. Performance metrics

The performance criteria associated with localization systems can be classified into the following areas

1. **Accuracy** refers to the closeness of a measured value to a standard or known value .High accuracy and fast convergence are very important issues for a good localization system .In this survey we compared many techniques depending on its accuracy and the accuracy of different systems or methods can varies from 3cm to 5 m as shown in table (2).
2. **Coverage** means the area covered for accurate localization. Since different wireless technology has a different distance, therefore, short-range wireless technology may require more devices to cover the same area.
3. **Localization time:** The time needed for localization for wireless based indoor localization varies for different methods.
4. **Adaptiveness** .Environmental influence changes may affect the localization system performance. The ability of the systems. Trade-offs between the system complexity and the accuracy affect the overall cost of the system.

N	Technology	Accuracy	Localization Technique	References	P-year	Environment
1	WI-FI	1-4.5	RSSI	Tang, Peng	2016	22 ×63 m and 19 APs (building)
2	Wi-Fi Assisted Multi-Floor with Inertial Sensors	1.5m	RSSI & Inertial Mea-Unit (IMU)	Li, Yifan	2016	multi-floor indoor environment
3	Wi-Fi	2-5m	Lateralation &RSSI	Shchek, Maxim	2015	Room with Furniture 25m2 -3APS
4	WI-FI	2-2.5m	RSSI	Bianca -B	2015	3Aps Room
5	WI-FI	~1m	RSSI	Wu, Zheng	2015	35x30m area
6	WI-FI	1.5m	RSSI	Hongbo Liu	2014	office12m × 11m
7	WI-FI	1.8-2.7	RSSI	Husen, Mohd Nizam, and Sukhan Lee	2014	demo room 4.5 X 3.6m
8	WI-FI	2m complex indoor environment	RSSI	Jiang, Zhi-Ping	2014	2000 m²
9	Wi-Fi	2.9-5m	RSSI	He, Xiang	2014	Lib 40m x 40 m



10	WI-FI	<3m	Fingerprint	Le Dortz	2012	Floor 65x 25m.
11	Wi-Fi	2-2.5m	Fingerprint	Jekabsons,Gints	2011	460 m² Floor
12	WI-FI	1.5m	Fingerprint	Martin,E	2010	Room
13	Combined Wi-Fi + beacons(6)	0.99m	RSSI	Kriz, Pavel, Filip Maly, and Tomas Kozel	2016	52m × 43m area, 6 beacons+4APs
14	Combined Wi-Fi +beacons(17)	0.77m	RSSI	Kriz, Pavel, Filip Maly, and Tomas Kozel	2016	52m × 43m area ,17 beacons+4 APs
15	I Beacon	8 beacons more accurate	RSSI	KARAKAYA, Murat, and Gokhan	2017	6x5 m2 grid 12 beacons
16	I Beacon	1.97m	RSSI	Zafari,F, and Ioannis	2015	11 x 6 m2 hall 8 beacons
17	Bluetooth	1.5m	RSSI	Fernandes, Tiago	2011	a room with 10x7 m3 beacons
18	FM/ DVB-T Signals	0.5m	Fingerprint	Carvalho, oberto	2016	office open area 6 FM C
19	FM	2.79-4.21m	Fingerprint	Moghtadaiee,V ahideh, Andrew	2014	23 m by 11 m 5 FmS
20	FM	Accepted 82%	RSSI	Chen, Yin	2013	Room 9x30 5 Fm tra
21	FM	6m	Fingerprint	Yoon, Sungro, Kyunghan Lee	2013	Different Class rooms 55mx85m 8 FM stations
22	FM	2.1m	RSSi	Popleteev, Andrei	2011	12x6 m Room FM transmitters
23	UWB & inertial sensors	3cm	TOA	Kok, Manon, Jeroen D. Hol, and Thomas B. Schön	2015	10 receivers deployed in a room 8 x 6 x 2:5 m+ 17 inertial sensors
24	RFID		Signal Propagation	Li, Junhuai	2013	area of 5*15m2 and area



		1-1.6m	Model & Fingerprinting			of 5*10m2.With 4 readers
25	RFID	30cm		Athalye, Akshay	2013	2x3 m2 3 tags
26	VLC	3cm	RSS/TDM	Yi, Keon Young	2015	40cmx170cm 16 LED
27	VLC/3D	3 cm	LED	Yang, S-H	2013	2x1.5x1.5m lab,3 LED
28	VLC	20cm	LED	Vegni, Anna Maria	2012	Room 8x10x2 4 LED transmitters
29	ZigBee	1-3m	RSSI	Alhmiedat, Tareq, Ghassan Samara	2013	office test environment 41.5x11.3 & Sports hall 30.5x11.3 3 sensors
30	ZigBee	2m	RSSI	Chuenurajit, Thanapong	2012	Room Area of 5 × 5 × 2m 8 Z –nodes

Table 2. Accuracy of different indoor positioning systems

IV. PRIVACY AND SECURITY

The two most used privacy definition concern user control over data, and the prevention of data-leaks [40]. Information privacy is the right to have some control over how your personal information is collected and used.

The main challenge facing the adoption of wide scale localization services is the privacy. Most subscribers or users do not want to share data about their position. This is because the user's position is one of the most sensitive information and can expose user privacy and security to risk .The protection goals of the user defines which attributes of the information must be protected and which can be revealed as spatial information(his position),and temporal information(time).

privacy is a major challenge that the researchers have to address. How can we ensure that user who uses localization services will not have privacy issues and will keep user data safe and confidential and only used for specific purposes . Moreover, how can the user trust the system and the localization service provider? If the authentication mechanism is weak, a malicious node can infiltrate the system and carry out a systematic attack against the localization system that will certainly affect the overall performance of the system.

Protection goals :-

- **User's identity**

To ensure the privacy is to hide the user's identity while the position of the anonymous mobile object is visible to clients. The identity of a user can be his name, a unique identifier, or any set of properties uniquely identifying the user. If a user publishes position information without personal information, an attacker can still try to derive the user's identity by analyzing the position information and additional context data such as the visited objects[40].

- **Temporal information**

Temporal information defines the point in time or time period when the spatial information of the user is valid. In some scenarios, spatial information is only considered critical if it is associated with temporal information.



Some techniques used to insure the privacy as shown in table (3).

no	Technique used	Title	Reference	P-year	Privacy measuring
1	Regression analysis method	Privacy-preserving indoor localization via light transport analysis	Zhao,Jinyuan,Prakash	2017	Not violate
2	Privacy vs. Reward for Location-Based Service	Privacy vs. Reward in Indoor Location-Based Services	Fawaz, Kassem.	2016	guarantees
3	Temporal Vector Map (TVM)	Privacy-preserving indoor localization on Smartphone's	Konstantinidis, Andreas.	2015	guarantees
4	multi-lateral privacy-preserving	Protecting multi-lateral localization privacy in pervasive environments	Shu, Tao, Yingying C	2015	Prevent
5	Crowdsourcing model	Efficient Privacy-Preserving Fingerprint-Based Indoor Localization Using Crowdsourcing.	Armengol, Patrick.	2015	NA
6	Fair Rendez-Vous Problem (FRVP)	Privacy-preserving optimal meeting location determination on mobile devices.	Bilogrevic, Igor.	2014	fully privacy-preserving
7	user-centric location based service architecture	Exploiting service similarity for privacy in location-based search queries	Dewri,Ramakrishna.	2014	NA
8	Privacy-Preserving Wi-Fi Fingerprint .L- scheme (PriWFL)	Achieving privacy preservation in Wi-Fi fingerprint-based localization	Li, Hong.	2014	NA
9	location-privacy preserving mechanism (LPPM)	Protecting Location Privacy: Optimal Strategy against Localization Attacks	Shokri, Reza.	2012	NA
10	multi-method approach	A privacy-respecting indoor localization approach for identifying shopper paths by using end-users mobile devices.	Bourimi,Mohamed.	2011	NA
11	Survey	How to Measure Privacy: a Structured Overview of Analysis Methods for Privacy-Enhancing Technologies	de Klerk, Tim	2016	High/Medium/Low
12	NA	Privacy Protection in Pervasive Systems: State of the Art and Technical Challenges	Claudio Bettini, Daniele Riboni.	2015	High/Medium/Low



13	Privacy-Enhancing PE (Private Equality) primitive.	privacy preserving method using privacy enhancing techniques for location based services	Buchanan, William J., Zbigniew Kwecka, and Elias Ekonomou.	(2013)	NA
14	Inner Product Encryption in a cloud environment	Privacy-preserving indoor localization based on inner product encryption in a cloud environment	Wang, Zhiheng, et al. "Privacy-preserving indoor localization based on inner product encryption in a cloud environment." Knowledge-Based Systems 239 (2022): 108005.(14)	2022	NA
15	Paillier encryption and garbled circuits	Practical Privacy-Preserving Indoor Localization Based on Secure Two-Party Computation	Nieminen, Raine, and Kimmo Järvinen. "Practical privacy-preserving indoor localization based on secure two-party computation." IEEE Transactions on Mobile Computing 20.9 (2020): 2877-2890.	2020	NA
16	Temporal Vector Map (TVM) algorithm	Privacy-Preserving Indoor Localization on Smartphones	Konstantinidis, Andreas, et al. "Privacy-preserving indoor localization on smartphones." IEEE Transactions on Knowledge and Data Engineering 27.11 (2015): 3042-3055.	2015	NA
17	Attribute-based Authentication (ABA) protocol that offers superior levels of privacy protection	Maximizing privacy and security of collaborative indoor positioning using zero-knowledge proofs	Casanova-Marqués, Raúl, et al. "Maximizing privacy and security of collaborative indoor positioning using zero-knowledge proofs." Internet of Things 22 (2023): 100801.	2023	NA
18	Wi-Fi time-based indoor localization system	Privacy-preserving by design: Indoor positioning system using wi-fi passive tdoa	Mohsen, Mohamed, Hamada Rizk, and Moustafa Youssef. "Privacy-preserving by design: Indoor positioning system using wi-fi passive tdoa." arXiv preprint arXiv:230-(2023).[40]	2023	NA

Table 3. different methods with privacy and security.

V. DISCUSSION

This survey discusses various scientific research methods, their workings, and techniques used to protect user confidentiality and privacy by preventing data disclosure or viewing.

VI. CONCLUSION

This survey explores indoor localization techniques, developments in WI-FI fingerprinting technology, and various research methods. Accuracy depends on factors such as technology, building type, noise, system design, coverage area, cost and localization time. Cost is an important criterion, as it requires more power consumption and device costs. Despite some progress, user privacy and security remain a major challenge, and more attention should be given to these aspects.

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