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Indoor Localization Techniques for Smart Building Environment

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Abstract

"Knowing the Location" and "Determining the Location" are the essential requirements of constructing a smart building. GPS technology, which is often used for the purpose of positioning, cannot be used efficiently while performing position detection indoors because of the losses occurring in the signal propagation. At the same time, the object of sensors, Bluetooth, IrDA and RFID devices which are commonly used in a building, and bandwidth constraints makes such location detection more difficult because of possible energy consumption and limited memory capacity. Since WiFi technology which will probably be used in nearly all Smart Buildings, Indoor localization algorithms have been surveyed and requirements which are essential for obtaining Internet of Things (IoT) technology have been researched, and a context-based approach for a Smart Building which has got IoT structure is proposed.

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Keywords: Internet of things, indoor localization, smart buildings, WiFi localization

1. Introduction

Internet of Things defines detecting of equipment and systems from machine to machine with the use of RFID readers, barcode technology, two-dimensional bar code devices, the GPS system and the use of short - range wireless sensor networks. In short, the Internet of Things concept transforms the connectivity principle of for "every person ", "everywhere" and "always on" into the principle of " every object " to " always " and " everywhere "[1]. Creating Internet of Things concept plays a crucial role when designing a smart structure building with which location determination can be done. Each object can access each other anywhere, any time which will allow objects to communicate and identify the correct location permanently. For this purpose, it is necessary to design the

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algorithm to determine an effective internal location for the Internet of Things. In an Intelligent Building of which a structure of the Internet of objects established both human, object and task management and human, object and service orientation can be done. Your mobile phone could tell you where in your home you have left your watch, and your watch will be able to show the shortest route to the clinic that you want to go for the first time.

The location which can act in accordance with the location for Humans – Object – Service communication can be known. Table 1 shows scenarios of localization in terms of job, object and services.

Table 1. Humans-Objects-Service communication

Humans	Things	Services
What's the position of people in the building?	Where is the object in the building?	What's the position of people or objects in the building?
What were the positions the person passed through before reaching his existing position?	What were the positions the object passed through before reaching its existing position?	Which positions and units have been passed through while achieving the related services?
What are the positions the person most frequently passes through?	Which position is the most available one to reach the object?	Through which positions the service is followed?
What's the simplest way to reach one's target?	What's the simplest way for objects to reach each other and people to reach objects?	Which path should be followed for the communication of service, object and people?

2. Indoor WiFi Localization Techniques

Indoor localization can be done by using IrDA, Ultrasound, Bluetooth and Radio Frequency technologies. However, the Radio Frequency; especially encountered in almost every building, has a certain infrastructure, including low-cost and medium-wide use in the field of WiFi networks will facilitate the smart building design. In a WiFi network, deterministic or probabilistic localization methods can be used [2]. Deterministic methods can estimate localization faster by using classical measurement techniques like Trilateration and Triangulation. They use a simple signal strength map in which each location has a list of objects, humans or services within range and an average value of signal strength. Deterministic methods, despite using a simple calculation than probabilistic methods, probabilistic methods estimate the location by precisely considering where the object is located in the current measurement. Because of the fact that probabilistic methods require much information than deterministic methods, they perform more accurate location detecting comparing to the deterministic methods [3] [4]. However, they are ineffective for small-capacity devices such as sensors, because of having computing density. Particle Filters, Kernel Method, Histogram Method, the Hidden Markov Model Methods are some of the probabilistic methods [2].

Measurement algorithms that can be used for localization; Trilateration, Triangulation, Scene Analysis, Dead Reckoning, Proximity and Hybrid Algorithms are researched and can be seen in Table 2.

- Trilateration Algorithms: Trilateration method measures distance to the station from mobile devices. Received Signal Strength (RSS), Time of Arrival (ToA), Time Difference of Arrival (TDoA) are some of the measurement techniques of Trilateration Algorithms. They need to know at least three mobile devices' location for the first step for an efficient localization [5].
- Triangulation Algorithms: These algorithms are suitable to use especially in Line of Sight communication. The angle of Arrival (AoA) or Angle of Departure (AoD) measurement techniques is some of the Triangulation Algorithms. The location determined by using the angle of signals from the mobile user

and the anchor nodes. If the angle of the signal changes because of multipath, those techniques may not work efficiently [6 7].

- Scene Analysis: Region based algorithms are used. Fingerprinting is one of the best-known Scene Analysis algorithms. Fingerprinting algorithms have got two phases which are training and localization. The commonly training phase is considered as offline, and detecting phase as online. Before the localization, some location information is gathered as offline. In this method signal strength may differ because of communication problems like fading, interference or multipath. Also, changes may occur in environmental factors, which may require retraining. At online phase; localization process is performed. Localization is performed by comparing the signal strengths at the online phase and offline phase.
- Proximity: Proximity measurements simply report whether or not two devices are 'connected' or 'in-range' [8]. Locations based on closeness to known reference points, coupled with a widely deployed wireless technology, can reduce the cost and effort for localization in local and indoor areas [9].
- Dead Reckoning: Specially used by the sensors. Localization algorithm works according to the last known or estimated location by using velocity or acceleration. It uses internal navigation system which presents highly accurate location information. Every location measurement is realized by using older steps. As a disadvantage; measurement errors can increase at every step.
- Hybrid Algorithms: Hybrid algorithms are often created by usage of probabilistic and deterministic algorithms together. For indoor localization multipath, interference and fading commonly occur problems. Also, every building has its own disadvantage. For creating an efficient localization algorithm, using probabilistic and deterministic algorithms together may rise the accuracy of localization.

Table 2. WiFi localization algorithms

	Trilateration	Triangulation	Scene Analysis	Proximity	Dead Reckoning	Hybrid Algorithms
Measurements Techniques	RSS, ToA, TDoA	AoA, DoA	Fingerprinting	RSS	Velocity Acceleration	Hybrid
Accuracy	Medium	Medium	High	Medium	Medium	High
Time Cost	Low	Low	High	Low	Low	Medium
Distance	Low	Low	Medium	Medium	Low	High
Algorithm Type	Deterministic	Deterministic	Probabilistic	Deterministic	Deterministic	Probabilistic Deterministic
Specification	Time Based	Direction based	Range based	Range Based	Time Based	Hybrid

3. Indoor Localization Specifications and Challenges for Internet of Things

The most important factor to be taken into account in the design of indoor positioning algorithm is mobility. Devices which are used in a network can be fixed and mobile, and can also be active fixed, passive fixed, active and passive mobile.

Moreover, Internet of Things Technology should not only support the mobility of users, it should also support terminal, session, service and spectrum mobility [10]. Satellites technologies like GPS which facilitates determining outdoor positioning cannot be used for indoor positioning efficiently because of not providing a line of sight.

At the same time, interference and noise are the other problems that occur while GPS technology is used for indoor positioning. Therefore for constituting a “Smart Building” using diverse technologies like RFID, Sensor, Bluetooth under WiFi networks which have got low price requirement, would be effective for mobility management and localization.

But indoor localization is always challenging. An indoor localization may provide unstable environment In the building, signals may be in a temporal, small or large area. Signals may encounter problems like interference, reflection, noise, non-line-of-sight, multipath which can decrease the accuracy of communication [2 11] .

To assess the performance of localization algorithms in Internet of Things, there are lots of metrics: precision, accuracy, complexity, scalability, robustness, and latency to be considered [12 13]. Accuracy for localization cannot be obtained efficiently without other metrics. In an IoT network, depending on the movement objects, humans and services are likely to change location rapidly. IoT structure which can be used in indoor networks that support real-time data access and loT localization algorithms must take into consideration all of these metrics. At the same time, IoT network must take into consideration location change not only provided by the mobility of the user but also provided by terminal, session, service and spectrum mobility.

Therefore, to determine the location algorithm for the Internet of Things; while designing algorithm coverage, bandwidth, delay, CIR (Carrier to Interference Ratio), SIR (Signal to Interference Ratio), BER (Bit Error Rate), cost, level of security, speed, battery power, current location information, user profiles, preferences, variables such as service capacity should also be considered for establishing new performance metrics. Moreover, to create a system which all objects, humans, and services can access each other anywhere, anytime knowing the position (with coordinates) is not necessary. Objects, humans, and services can also be accessed with the symbolic or relative positioning techniques [14]. The answer would be for the symbolic positioning like: at home or not at home. But the relative positioning techniques, a referenced object's (position known in advance) position can be calculated according to the proximity of an object.

Another way to obtain the location information of the objects, humans and services are to use the structure of hopping. For accessing the desired service; a reference position which an accessible object, human or service is used for calculation. When designing the IoT algorithm for determining the position of an object. The most important variable to be considered is the content. In particular, real-time based IoT networks, in the case of emergency, in applications requiring high precision and attention, handling the change of content is very important in order to provide continuity. Content data flow should be constant and have high speed. The contents of objects, humans or services in the IoT network may be subject to frequent change; they can be updated.

RFID technology is a technology that can be used in IoT networks frequently, because of having low price cost and it can be used almost anywhere. By using RFID technology, a different ID can be given for each device easily [15]. In this way every object, human, and service can be accessible, the content may easily be collected. However, due to the limited memory capacity and low data transfer speed that have RFID devices, they cannot help to determine the location in the network. Sensors which have a higher ability to manage themselves (self-organizing), and capable of collecting more comprehensive content, can operate hopping in the network. Sensors should take place in an IoT network for location detection. Some statically located sensor can radiate beacon signal, localization can be done by using beacon signals [16]. In a WiFi network RFID devices are very helpful to collect content information; on the other hand, sensors are very helpful for measuring location information.

4. An Approach for WiFi Based Localization in Internet of Things

Due to the high localization accuracy and high information context required by the objects, humans, and services IoT will greatly consist of from the use of RFID and sensor devices. To provide an IoT network each object, in all places, at all times policy, it must determine localization detection by using especially context-based policy. Therefore, to perform their duties well the location determining objects in the IoT network, IoT must consider the context information. A user in a network making the request may not only wish to have access to a single context may also wish to access a context service that can be formed by the merger of multiple contexts. For example, the administrator may want to lead workflow in a factory, where there is a minimum product in the production line, with the most materials and which has the most personnel to perform the job as of the moment. In this case, it is needed to determine the location of personnel within a building, and calculate the number of products in the production line and material found in the unit. In order for all this information to be processed, and be directed to the relevant units of the workflow, one should have access to at least three different contexts and should interpret three different contexts. In this case, in order to work under IoT structure, a context aggregator (gathering), context unifier (extracting) and context interpreter (organizing) are seen as needed.

Designed Indoor localization algorithms should be interoperable with a context management mechanism. The location within the structure of the Internet of Things cannot work efficiently without knowing "context" information. In an IoT network which is located indoor, it is likely to be faced with all the problems in WiFi communication. Noise, interference, signal fading, multipath are some of the problems of all objects that can be found in each particular location within the building and is further magnified when considering the need to communicate with each other. Therefore, a hierarchical structure based on the context of the object, as hopping, will reduce these problems to be encountered in buildings when communicating.

Designing a smart building requires the use of many different technologies like RFID, Sensor, NFC, IrDA, Bluetooth and the network inside of a smart building will generate a heterogeneous network. Carrying out the process of detecting the location of a heterogeneous network is particularly challenging. Deterministic methods for detecting a location that does not always provide high precision. Because of that in an IoT network, deterministic algorithms may not effectively be used for localization. The algorithms that use probabilistic methods relatively require more time. Continuously changing the object, human and service triangle and methods using algorithms will have a high time cost. In a Smart Building which has got IoT, Context-Based Hierarchical Localization is needed. Fig. 1. shows the flow of the proposed approach. While the context information which is collected from objects, humans and services must be gathered by the Hierarchical Context Manager; the location measurements which are collected from objects, humans and services must be gathered by Localization Manager. Deterministic and probabilistic algorithms must work together, instead of using only one of deterministic and probabilistic algorithms for Hybrid Localization Algorithm that should be designed for using Localization Manager. Evaluating the localization measurements by a Hybrid Algorithm which deterministic and probabilistic methods are used together, will provide high precision, accuracy, and low time cost. By using the information, which is gathered from Hierarchical Context Manager and Localization Manager, Hierarchical Context-Aware Localization (extracting) can be done, objects, humans, and services can have localization service by using this knowledge (organizing).

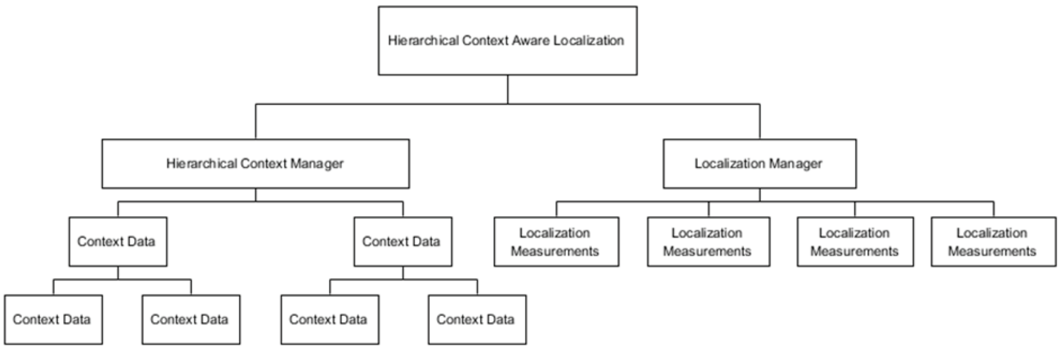

Fig. 1. Hierarchical context-aware localization

Although, because of problems WiFi networks can have, usage of those algorithms cannot be sufficient for localization. After measurement techniques are used, especially deterministic ones, for handling problems like interference, multipath, signal fading or noise location correction algorithms may be used. Nearest Neighbours, Bayesian Classification, Decision Tree, Neural Networks, Support Vector Machine (SVM), Smallest M-Vertex Polygon (SMP) are some of the location correction algorithms.

5. Conclusion

Ability to access the location of corresponding objects, people and services are one of the basic requirements of a smart building environment. Designing Internet of Things is a very important issue for smart buildings because of the usage of many different technologies in a building. For this reason, WiFi localization algorithms have been searched for designing an IoT localization algorithm in this study.

For a localization algorithm of an IoT structure which works under a WiFi network, using deterministic algorithms like Trilateration, Triangulation, Scene Analysis, Dead Reckoning, Proximity or probabilistic algorithms like Fingerprinting alone may be insufficient. RSS, AoA, TDoA are not suitable to be used for Smart Building localization because of the requirements of high mobility and dynamic changes that IoT networks have. The Fingerprinting algorithm is a probabilistic algorithm since it needs the introduction of the system that will be studied in advance; it requires a basic training phase structure of IoT that does not fit the concept of "every object" to "always", "everywhere" communication. Usages of probabilistic algorithms are not enough for an ever-changing structure since they only set out from the initial conditions. Therefore, an IoT localization algorithm, which is designed to determine the location of objects must be a hybrid algorithm, specifically takes into account the concept “context”. A Smart Building localization algorithm must take into account the hierarchical structure of services, humans, and services; and it must be an algorithm supports hierarchical context based, hopping communication system. For future work, a new Hierarchical Context-Aware Localization Algorithm which has got a hybrid measurement algorithm will be studied for a Smart Building.

References

1. Atzori L, Iera A, Morabito G. The Internet of Things: A survey. *Comput Networks*. 2010;54(15):2787-2805. doi:10.1016/j.comnet.2010.05.010.
2. Bagosi T, Baruch Z. Indoor localization by WiFi. *Proc - 2011 IEEE 7th Int Conf Intell Comput Commun Process ICCP 2011*. 2011:449-452. doi:10.1109/ICCP.2011.6047914.
3. Zekavat R, Buehrer RM. *Handbook of Position Location: Theory, Practice and Advances*.; 2011. http://ieeexplore.ieee.org/xpl/bkabstractplus.jsp?bkn=6047597.
4. Yu F, Jiang M, Liang J, et al. An Indoor Localization of WiFi Based on Branch-bound Algorithm.
5. Kul G, Özyer T, Tavli B. IEEE 802.11 WLAN based Real Time Indoor Positioning: Literature Survey and Experimental Investigations. *Procedia Comput Sci*. 2014;34:157-164. doi:10.1016/j.procs.2014.07.078.
6. Kabir AL, Saha R, Khan MA, Sohul MM. Locating Mobile Station Using Joint TOA/AOA. *Proc 4Th Int Conf Ubiquitous Inf Technol Appl (Icut 2009)*. 2009:433-438. doi:10.1109/ICUT.2009.5405682.
7. Wenjie W, Bobin YAO, Qinye YIN. AOD estimation in WSN localization system with synthetic aperture technique. 2012;55(10):2216-2225. doi:10.1007/s11432-012-4640-5.
8. Bridal P, Diiha J, Krasnovsky M. On the Accuracy of Weighted Proximity Based Localization in Wireless Sensor Networks 2 Mobile Localization in Wireless Networks. In: *IFIP — The International Federation for Information Processing*.Vol 245.; :423-432.
9. Korkmaz A. DISSERTATION : ON PROXIMITY BASED SUB-AREA by Submitted to the Graduate Faculty of Telecommunications and Networking Program in partial fulfillment of the requirements for the degree of Doctor of Philosophy University of Pittsburgh. 2011.
10. Mwangoka JW, Marques P, Rodriguez J. Cognitive mobility management in heterogeneous networks. *Proc 8th ACM Int Work Mobil Manag Wirel access - MobiWac ’10*. 2010:37. doi:10.1145/1868497.1868504.
11. Makki A, Siddig A, Saad M, Bleakley C. Survey of WiFi Positioning using Time-Based Techniques. *Comput Networks*. 2015;88:218-233. doi:10.1016/j.comnet.2015.06.015.
12. Liu H, Darabi H, Banerjee P, Liu J. Survey of wireless indoor positioning techniques and systems. *IEEE Trans Syst Man Cybern Part C Appl Rev*. 2007;37(6):1067-1080. doi:10.1109/TSMCC.2007.905750.
13. Hossain AKMM, Soh W. A survey of calibration-free indoor positioning systems. *Comput Commun*. 2015;66:1-13. doi:10.1016/j.comcom.2015.03.001.
14. Disha A. A Comparative Analysis on indoor positioning Techniques and Systems. *Int J Eng Res Appl*. 2013;3(2):1790-1796.
15. Xiong Z, Song ZY, Scalera A, Sottile F, Tomasi R, Spirito MA. Enhancing WSN-Based Indoor Positioning and Tracking through RFID Technology. *2012 Fourth Int EURASIP Work RFID Technol*. 2012:107-114. doi:10.1109/RFID.2012.26.
16. Han G, Xu H, Duong TQ, Jiang J, Hara T. Localization algorithms of Wireless Sensor Networks: a survey. *Telecommun Syst*. 2013;52(4):2419-2436. doi:10.1007/s11235-011-9564-7.