IoT Smart Homes based on RFID Technology: Localization Systems Review

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ABSTRACT

Internet of Things (IoT) become one of the buzzwords in the Information Technology. It an ecosystem of technologies monitoring the status of physical objects, capturing significant data, and communicating that information to software applications through IP networks. Today, Indoor localization systems based on underlying technologies like RFID have been designed and used to locate the movement of objects and subjects in the indoor environment. This technology finds its use in various indoor localization applications ranging from healthcare, tracking people and objects in real time to helped living in the smart environment and many more. The technology of RFID is known very convenient due to many benefits of flexibility, automatic identification, its cost effective and its energy efficiency. This paper presents some IoT Smart Homes applications based on RFID technologies. its presents also a number of comparable studies and discusses the techniques, applications, algorithms, and challenges presented during the integration of RFID technologies in IoT smart home systems.

Categories and Subject Descriptors

C2.1 [**Network Architecture and Design**]: Network communications, wireless communication.

Keywords

RFID; Localization Technique; Smart Homes; IoT.

1. INTRODUCTION

The internet of things (IoT) allows people and things to be connected anytime, anyplace, with anything and anyone, ideally using any path or network and any service [1]. Fig.1 illustrates the context where there is interconnection between people and things and/or between things. This technology provides not only the communication of things with each other, comfort and safe environment, but provides some manners to minimize the role of humans and reduce his errors for control, monitoring, diagnosis of objects and give a chance to construct an intelligence network into Internet of Things [2, 29, 30,31,32,33]. We can consider some examples that are remotely controlled over the internet in smart home system like receiving a fire alert notification, opening or closing doors and turning off or on electrical appliances. Therefore, these benefits allow the smart home systems to optimize the services, increase the quality/precision of data collected, make a good decision from the user and improve live quality. The concept of Smart Homes is defined as a location inside equipped with computers and technological devices [3,30].

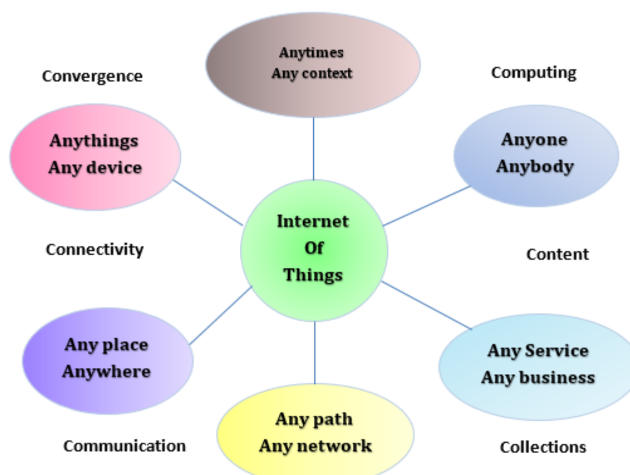

Figure 1: Internet of Thing interconnections.

In the last few years, Localization in indoor domains or environments act an important role in IoT. Indoor localization systems based on underlying technologies such as RFID [4], Zigbee [5], Bluetooth [6] and Infrared [7] have been adapted and employed to various applications like healthcare, locate the

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movement of objects or subjects and assisted living in the indoor environment. Radio Frequency Identification (RFID) become one of the promising technology that is engaged to revolute many industries due to its cost-effective and energy efficiency characteristics. The adoption of RFID continues progressing everyday but may challenges are still needed to be investigated.

In this paper, we provide an overview of internet of things smart home and role of RFID technology and its real-time applications for the usages in our daily life. In section 2, we discuss the evolution of RFID technology under smart home systems and their challenges to adopt RFID in IoT smart home localization solution. Section 3 recalls some localizations techniques and RFID solutions. This section provides also a comparative study of these solutions for localization systems in Smart Homes. Section 4 concludes the paper.

2. RFID AND SMART HOMES SYSTEMS

RFID is an advisable technology for localization in IoT. Tracking stationary movable objects and persons is a subject of a several researches due to the challenges presented during implementing, adopting and optimizing of indoor positioning systems. RFID has been considered a promising technology in indoor positioning environments [8].

RFID (Radio Frequency Identification) systems are very useful and convenient to identify objects automatically through wireless communication channel. RFID systems are generally consisted of tags, readers, and the back-end server connected to the reader as seen in Fig.2. The information captured by RFID tag is sent back to reader for further location processing. In these days, RFID system is increasing and applied to various tracking applications such as asset tracking, supply chain management, security, healthcare assets tracking, etc. The low cost of RFID technology and the assured form of automatic identification allow it to be used for localization in indoor environments. Otherwise, issues related to RFID tags performance and collision among other tags present some serious challenges in implementation of RFID localization technologies in IoT smart homes. For tracking, there are two ways that readers can be installed inside the household. Static location where reader searches for the tags which are attached to objects or person. And mobile location where reader try to detect the constant tags positions [9].

There are three main types of RFID tags; Active tags, Passive tags, Semi-active tags. Active and passive tags are very different, but it can be noted that active tags receive the energy needed from internal battery, while passive tags have no power supply by them, using the energy of electromagnetic radiation emitted by the tag reader, having less range and scope reading than active tags. Passive tags are less costly with long life, and also small dimensions. Another type of tag is also semi-active that in addition to its internal battery use, it can use the energy waves emitted by the tag reader

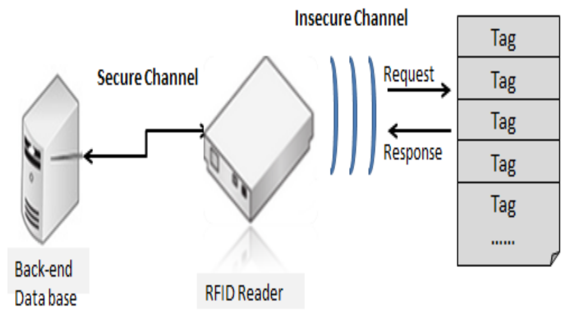

Figure 2: RFID Technology system.

2.1 RFID Indoor Localization Techniques

Many RFID localization techniques are proposed by several researches. The main position estimations and detection methods are distance estimation (Triangulations), Proximity and Scene Analysis (see Fig.3).

2.1.1 Triangulations

Triangulation uses the geometric properties of triangles to determine the target location as shown in Fig.4. It has two derivations: lateration and angulation. Techniques based on the measurement of the propagation-time system (e.g., time of arrival (TOA), RTOF, and time difference of Arrival (TDOA)) and received signal strength (RSS) based and received signal phase methods are called lateration technique [10, 11]. The Angle of Arrival (AOA) estimation technique is also called an angulation technique.

2.1.2 Scene Analysis

Most indoor localization approaches adopted fingerprint matching as the basic scheme of location determination [12]. 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.

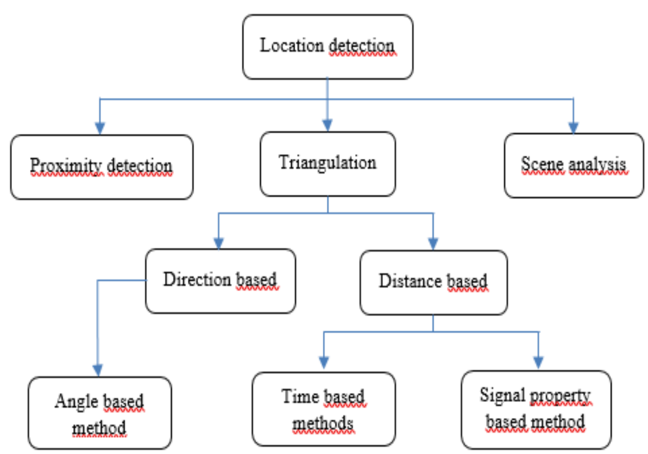

Figure 3: Location detection based classification.

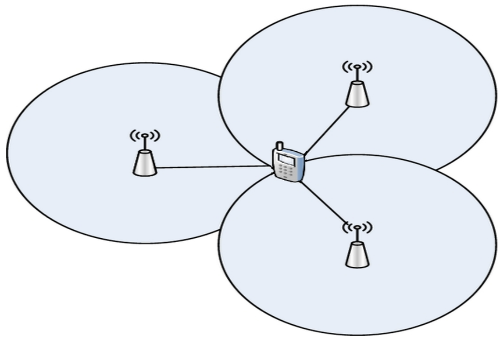

Figure 4: Positioning based on TOA/RTOF measurements.

The location of an object is then found out by corresponding online measurement with the closed position against the database. Positioning based on TOA/RTOF measurements. pattern recognition techniques including probabilistic, k-nearest-neighbour (kNN), neural networks, support vector machine (SVM), and smallest M-vertex polygon (SMP) [12].

2.1.3 Proximity Detection

This method is one of the simplest positioning methods to implement. It provides symbolic relative location information. The position of mobile target is determined by cell of origin (CoO) method with known position and limited range. When more than one antenna detects the mobile target, it simply forwards the position nearest where the strongest signal is received. However, the accuracy of CoO relates to the density of antenna point and signal range.

2.2 Challenges analysis

To process automatically information about peoples' locations such as their movements around the house for remote health monitoring Smart Home systems, the accuracy should be required from these systems to track the locations of people. However, energy efficient indoor positioning solutions remain an open research challenge.

2.2.1 Accuracy

Accuracy of a system is the important user requirement of positioning systems. Accuracy can be mentioned as an inaccuracy distance between the estimated position and the actual mobile location. Therefore, the higher the accuracy is or better location measurement is, the better the system is. So, many factors affect the precision of the captured location:

- The localization technique used in indoor environment.
- The technology and capability of the device in use.
- The size area.
- The distance between targeted objects and sensing devices (e.g. sensors and readers) and physical obstructions.
- The orientation of tagged objects from sensors.

2.2.2 Complexity

This an important factor during design step of smart homes. Connecting more components to the existing or implemented solution will result in more complex system and the system requires more frequent maintenance.

2.2.3 RFID Localization Systems Challenges.

The variation of functionalities and principles in localizing objects and moving subjects in indoor environments are the main challenges of RFID tracking and location systems. Many indoor localization solutions are proposed by researchers to find the optimal solution that should be worked on several indoor positioning platforms. However, there is no wholly optimal in RFID technology.

2.2.3.1 Behavior change of RFID Tags and reader

The most common issue in RFID localization systems is RFID tags and readers behavioral changing in received signal strength indicator (RSSI) signals. The RSSI can be different for tags that are functional in the same conditions. This change of behavior can be caused by a defect during manufacturing related to integrated circuits and noise [13]. To control this abnormal behavior of RFID tags, more approaches are proposed to calculate and detect the RSSI change.

The common problem in RFID tracking system is that RFID readers are not able to totally query the tags within reading range [14]. To bypass this issue, it's recommended to increase the power level and optimize the distance between readers and tags within agreed reading range with no change the RSSI reading.

2.2.3.2 Interference issue

It's a result from radio noise and collision caused by liquids and metals that bloc the propagation of RF signal. This issue can be present in both active and passive tags in localization. But the interference problem is less detected in active mode tracking. UHF RFID interference can be divided into three types including tag interference, multiple readers to tag interference and reader to reader interference [15]. Study has suggested to mitigate localization errors caused by interference such as described in [13]. Unfortunately, further investigation is required to produce better and more scalable results.

2.2.3.3 Sensitivity Tags orientation challenges

To let reader, detect the tag's location the tags orientation factor is very important. To obtain better detection, tags can be attached vertically, horizontally or at an angle on the sides of objects.

Sensitivity of the tags is another issue in RFID localization applications. It defines the minimum power required to activate or read the tags. Tags with higher manufactural sensitivity provide better location detection [13].

2.2.3.4 RFID localization algorithms comparation

The following Table 1 compares diverse RFID localization algorithm for smart homes indoor environments. We can find one or several localization methods in each localization techniques and only few localization techniques are able to track in both 2 and 3 dimensions. Therefore, choosing a localization method to a given application is related to system requirements in indoor environment and the localization application area.

Table 1: Comparison among the common RFID localization methods.

RFID localization Technique		Method Algorithms	Dimension	Advantages Disadvantages	Ref.
Distance Estimation	Lateration Triangulations, Time based, phase based and Tag Range based Techniques	TOA	2D	A : High precision localization D:direct TOA suffers from synchronization and time-stamp multipath effect.	Shen et al [16]
		TDOA	2D	A: Accurate for Real time locating (RTLS) D: NLOS Multipath	Kim et al [17]
		RSS	2D, 3D	A: -Cost effective method of location estimation -Better estimate of the distance. D: uncertainty location related issues.	Chawla et al [18]
	Trilateration and Multiliteration		2D, 3D	A: high level of accuracy D: - Require to use at least reference points to perform distances calculation - measurement errors,	Bouchard et al [19]
	Angulation	AOA	2D, 3D	A: no synchronization required D: multipath reflections	Azzouzi et al [20]
Scene Analysis (fingerprint)		Probabilistic Approach	2D, 3D	Based on Bayesian network [86] to estimate target (tags) location.	Seo et al [21]
		k-nearest-neighbor (kNN)		Radio mapping based in online RSS.	Ni et al [22]
		Neural Networks method		It uses offline RSS and a-like location coordinates as an nput for the target training purpose.	Moreno-Cano et al [23]
Proximity		Reference Points (Well-Known position)	2D	A: offer proximate position information D: cannot give bsolute (relative) position	Song [24]

3. RFID LOCALIZATION RESEARCH PROJECTS IN SMART HOMES

RFID Localization of persons and objects is still a main and challenging issue in Smart Home that is taken in account by many researchers to adopt an inexpensive solution for tracking objects in the indoor environment. Numerous hybrid approaches are provided for better localization but these works add cost and complexity to the systems. Many factors were taken in account in those projects, such as, precision, accuracy, cost, complexity, scalability and adaptability in indoor positioning.

RFID technology cannot be used only in indoor tracking but can be also applied to many areas such as the industrial, automobile, agriculture and medical fields due to its advantage in accuracy, cost, efficiency, adaptability, scalability, robustness and low complexity. Table 2 describes a comparative list of RFID localization approaches solutions for indoor smart homes.

Table 2: Comparison of RFID localization solutions for Smart Homes

Solution Approach	Application	Accuracy Efficiency	Localization Technique	Reader Tags Area m/m2/m3	Advantage / Disadvantage
LANDMARC, 2004[25]	Location Sensing	≤ 2m	References tags	9/64	- Cost effective solution. - Less infrastructure required during deployment - Minimize the localization error (more precise).
		1m 5.9m	Active tags	NA	flexibility and Complexity such as: - Long latency. - Different tag behaviour during detection (different reading values)
FLEXER, 2006 [26]	Indoor localization)	40cm-1m	Reference tags	4/64	- Flexible localization method. - Reduces computational load and enhances the localization speed
		70cm	Active tags	49m2	System used Active tags (high cost, battery requirement) System complexity implementation.
Joho et al, 2009 [27]	Indoor localization	27cm-29cm	References tags	1/350	Probabilistic sensor model (Sensor calibration) based on

Solution Approach	Application	Accuracy Efficiency	Localization Technique	Reader Tags Area m/m2/m3	Advantage / Disadvantage
	(mapping)				RSSI to improve the accuracy of the system
		$\approx$ 35cm	Passive Tags	N/A	High cost as adding more tags will add extra costs to the system
Chawla et al, 2011[18]	Indoor localisation (object localisation)	0.18cm	References tags	1/132	Several algorithms to achieve higher accuracy and efficient solution
		0.35cm (overall average)	Passive tags	8m	- Need to deploy a large number of tags for higher accuracy - High complexity and installation issues
Xiong, Song et al, 2013 [28]	Indoor Tracking (people/ objects)	1.6m	RSSI	NA	- Cost effective approach (combined WSN with RFID devices) - Robust IPS solution
		1.8m (hcEKF algorithm)	Hybrid RFID Passive Tags/WSN	3002	System was not tested in a large scale experimental space.
		48 cm	Passive tags	4m*2m	- Requirement of landmark tags for localization application. - Relying on semi-passive tags (needs battery changes).

4. CONCLUSIONS

This paper discusses various algorithms and adopted techniques in RFID localization and presented these techniques according to sense analysis, distance estimation and proximity. We highlighted the advantages and disadvantages of each localization techniques for passive and active RFID systems. We reviewed the challenges facing the integration of indoor RFID localization. This study explains the need for a new approach that improves the passive RFID localization method. Future works will be focused to find a method to adopt and implement a cost-effective hybrid technology solution that improve the accuracy of locating and tracking of peoples and objects in smart environments.

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