IoT Based Localization and Tracking

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***Abstract*— Internet of Things (IoT) has several applications which directly affect our lives. IoT has been proposed to be part of the connected living paradigm. In this pool of applications, we also have localization based services. In the first one, localization of objects, animals and other living beings are determined using IoT. In the second one, the movement of the animals, kids, elderly and other moveable objects are tracked. Both localization and tracking are part of security and surveillance services in the connected living environments. In this paper, we provide the current state of the art for IoT based localization and tracking. We show the key technical aspects, compare the IoT based initiatives for localization with the non-IoT based services and finally show their utilities in different application domains. IoT based localization and tracking are found to be more pervasive and accurate than the previously used techniques.**

Keywords—Internet of things (IoT); localization of objects; tracking; tracking of animals; tracking of human

I. INTRODUCTION

The Internet of Things (IoT) is a paradigm shift in the enhancement of the connectivity of the Internet. It provides the technical feasibility for a huge number of sensors, actuators and smart devices to remain connected with it. It adds several emerging services which are essential for connected living initiatives. Among those value added services, localization is one of the prominent one. Localization has a lot of importance in the connected living environment such as security, surveillance and maintenances of law and order. Localization of moving objects leads to tracking which is essential for similar applications. Both localization and tracking are required for emerging applications in several sectors.

Localization and tracking of objects and are not very new applications. Satellite based object tracking has been used since 1960s when NASA started tracking the US naval ships and submarines [1]. In the 1970s, these localization and tracking applications were enhanced using several satellites by both the US and the USSR [2]. The US department of defense lunched its special tracking and localization satellite in 1978 [1]. Since then, several initiatives have been taken across the globe in this regard. The full fledged global positioning system (GPS) of the US was started in 1993 [1]. Similarly, the full operation of Russian positioning system GLONASS was started in 1995 [2]. Recently, the IoT based localization and tracking have got a large attention due to their ubiquity and accuracy in these functions [3]. There are several new methods being proposed to exploit these IoT scenarios. In [3], a Kalman filtering based approach has been proposed to extract real-time localization and tracking information of moving objects. The sensor data collected from the IoT nodes are analyzed using Kalman filters in this approach. In [4], localization of start devices has been determined using IoT information. In this method both trilateration and circle expanding techniques are utilized for the enhancement of both range and accuracies. In [5], indoor location based services have been studied using received signal strength indicators. In this work, Bluetooth has been studied extensively and based on the analysis from these studies, a motion assisted device tracking algorithm has been proposed. In the indoor environment, this algorithm provides better accuracy than other methods. In [5], another indoor localization and tracking method is presented in which the IoT devices of wearable are used for the ambient data collection. In this method a velocity tracking heuristic is used for the location and tracking determination. It has been found from [5] that estimation based on extended Kalman filters and the wearable sensors provide very good accuracy for indoor tracking. In [6], a bio-inspired approach has been adopted for IoT based tracking system. In this work, the authors used the methods followed by the bats for the navigation and tracking in WSNs. They extended it to machine to machine communications using ultra low power sensors. In [7], several algorithms have been developed for localization in both indoor and outdoor environments for wireless sensor networks (WSNs). In [8], main aspects of IoT have been discussed from the conceptual and architectural points of views. It provides the main functions of IoT nodes and their features for several sensing and communication related aspects. In [9], the authors emphasize the importance of IoT and its role in localization and tracking of objects in different applications. Crowdsensing, crowdsourcing and other localization applications have been highlighted in [10]. An IoT based school monitoring system has been presented in [11]. It shows that IoT based tracking of school busses is better than other

alternatives available. It shows the versatility of IoT based localization.

In this work, we present the current improvements in localization and tracking using IoT. We start with the differences between the IoT based localization and the non-IoT based systems. Then we show the suitability of IoT for localization and tracking. We show several current applications of IoT in localization and tracking.

The remaining parts of the paper are organized in four different sections. In Section II, we present the differences between IoT and non-IoT based localization and tracking systems. In Section III, we show the suitability of IoT for localization and tracking. In Section IV, we present several applications of IoT based localization and tracking. In Section V, we conclude the article with the main points.

II. IoT Based vs. Non-IoT Based Localization and Tracking

The term "positioning" has been recognized as one of the significant technologies in location-based services out of which Global Positioning System (GPS) plays a major role. The early GPS used to be a satellite-based navigation system made up of at least 24 – 27 satellites [1]. The tracking operation in a GPS system is based on the orbital parameters of at least three satellites that allow a GPS device to compute the precise location of the satellites. The principle of "Trilateration" is used by a GPS receiver where it locates objects, figures out the distances to each of the three satellites and deduces its own location [1], [2]. Though GPS systems can work under any weather conditions, its performance is good only in outdoor environments whereas in indoor environments its performance seems to be poor.

Cellular network based localization and tracking technique is a better solution because the base transceiver sections are available almost everywhere and their location is stable. Also, cellular based localization and tracking techniques require no additional hardware to be attached to a mobile device as every mobile can measure the signal strength. Using at least three measurements (from three cell towers or transceivers), the location can be determined. However, the wave propagation in a cellular environment is highly affected due to the changing channel characteristics leading to alteration in the signal strengths and hence does not prove to be a reliable parameter for localization and tracking.

Cellular positioning systems also use network based solutions to locate and track an object. Network based localization is a technique by which the necessary measurements are done by a network consisting of one or several base stations. The network – based localization scheme uses various methods such as Cell Of Origin (COO), Time of Arrival (TOA), Time Difference of Arrival (TDOA), Uplink Time Difference of Arrival (U-TDOA), Angle of Arrival (AOA), Assisted GPS (AGPS) and Enhanced – Observed Time Difference (E-OTD).

Wireless Sensor Networks have paved way for the development of many localization algorithms for both indoor and outdoor environments. The IoT combines the different technologies such as the Internet, Zigbee, Bluetooth, Infrared, Wi-Fi, to obtain location information from various objects. Localization and tracking in IoT maybe based on radio frequency, using optical sensors, sound wave sensors, and radio frequency identification (RFID). IoT devices that are connected together can monitor their environment while interacting between each other and gather data. This data can be used or exploited to enable new services. The smart home, for instance, can be quoted as an example. Non IoT devices on the other hand do not communicate with other devices.

RFID used in IoT is one of effective technologies in the indoor environments. It is equally effective in the outdoors as well. The RFID technology sends and receives the identity of users in a wireless environment using radio waves. The RFID localization methods include distance estimation to determine the target location, scene analysis where the features of the scenes are collected and then estimating the location of the entity and proximity in which the location of an entity depends upon the relative locations obtained from a group of antennas. IoT based localization and tracking is prove to be a connectionless, highly secure, high data rate service which is applicable to both indoor and outdoor environments.

III. Suitability and Justification of IoT Based Localization and Tracking

IoT has several features which are suitable for localization and tracking. IoT is a disruptive technology and it is very much ubiquitous. It is essential for sensing and communication at any remote location. In fact, localization and tracking may not be the primary purpose of the IoT deployment. Rather it can be added to any existing IoT as a value added service. This brings the beauty in to the system. In the smart city initiative, sensors will be deployed in every part of the city for monitoring and service provisioning which are

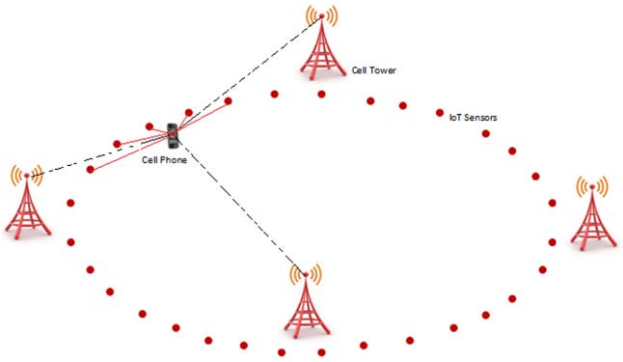

Fig. 1. Cell towers are less in number in comparison to the IoT sensors. Therefore, finding the locations using the IoT sensors is convenient and more accurate than using the cellular networks. In this case, we show the IoT sensors placed around an oval shaped ground and there are four cell towers around it. Certainly, IoT devices are better placed for localization.

commonly in demand for the citizens. Similarly, there are several other sectors such as manufacturing, healthcare, agriculture, policing, public emergency service provisioning too use localization and tracking. These applications use the locations of the IoT sensors and use them as references to determine the exact locations.

The accuracy of the GPS based localization with a ground reference is of the order of a few meters (i.e., the error in the location estimation is of few meters). Using the cellular towers, this accuracy can be further improved to less than a meter. However, the accuracy can be enhanced to a few centimetres using the IoT infrastructure. In Fig. 1, we show the scenario of an oval ground which has several IoT sensors deployed around it. It too has four cell towers to cover the whole ground. As shown in Fig. 1, there are several reference points if we take the IoT sensors for localization. However, there are very few (i.e., maximum four) when the cell towers are considered for this. The black dotted lines show the communication from the cell towers and the solid red lines show the communications from the IoT sensors. Wide scale deployment of IoT sensors makes it the popular choice for localization.

Tracking of objects and living animals is also very much possible using the IoT networks. Both object and animal tracking use the information associated with the sensors (attached with the objects and animals) and then keep sending the information to a master server. This server decodes the information obtained from the sensors and shows the path followed by the objects or the animals. These applications can provide several smart initiatives such as theft detection and smart policing. The sensors can also be deployed on human bodies as wearable and this can be used for tracking as well. IoT can be very effective as far as the energy efficiency is concerned. Narrowband IoT (NBIoT) is a low power wide area technology which can be regarded as a green technology. Thus both localization and tracking using NBIoT is very often considered as a green technology.

IV. Applications of IoT Based Localization and Tracking

IoT enables the smart devices to collect and exchange data through the network coverage and connections. Localization and tracking have become an integral part of the modern communication systems. Traditional location based services determine the specific location of a movable or unmovable object with the help of GPS through a wireless communication / Internet enabled device. In IoT based localization, it is simplified further and uses the IoT infrastructure to improve the accuracy. Tracking implies determination the trajectory of an object/animal/human in an environment where network or IoT coverage is available. Localization and tracking are the cornerstones of many applications including efficient security monitoring, green detection, surveillance, smart policing and pet/kids monitoring. These technologies have come into the play due to the need of the time and the advancement in mobile and wireless technologies that provide continuous Internet connectivity. All these together have given an edge to several new business opportunities such as location based devices and services associated with them. The importance of these services can be expressed by citing an example of mobile applications that got boost recently. For instance, in the difficult situations such as emergencies these services are very much essential in finding the nearest police station or hospital. Recently, during the process of demonetization in India these services played key roles such as ATM finding, cash or no cash in the ATM, updating the information about the nearby ATMs, cash availability and estimated wait time and crowd count. These services have flourished due to the dominance of smartphones, free availability of Wi-Fi in several cities and organizations. These services are normally deployed as value added services. Overall, they facilitate better data service provisioning and the charges for different mobile applications such as locating restaurants, healthcare facilities or other day to day demands have come down. It also provides the nearby law and order conditions through crowd sensing and crowd sourcing. Alerts on traffic conditions can also be provided using the IoT based road side sensors. In case of emergency such as road accidents, victims and culprits too can be located. Several other applications are available for free to ensure the security of women and children so that they can be easily located and tracked in case of vulnerable situations.

RFID technology allows object identification, localization and real-time tracking without compromising speed or reliability and finds its applications in military purposes. These technologies offer value added services that utilize the navigation tools to locate and track the users. Also the same information can be shared through short message services or any other social platform so that others can also track the users' location. This information is required for common public services such as finding cabs using Google maps. These services are also utilized by the cab service providers such as Uber, Ola and several other taxi companies.

Not just the outdoor applications, localization and tracking are effectively efficient in indoor localization of smart hand held devices using Bluetooth that explore user motion to track down the targeted device or equipment. RFID plays equally important role in the indoor environments. Wireless technologies have variations in different frequency bands; area of coverage which determines their unique characteristics when used for indoor localization such as proximity methods. They also use the common methods such as the approximate location and triangulation methods which are used outdoors. Use of angle arrival or distance based information received from different beacon stations or sensors to locate users are also popular.

IoT based localization and tracking are very much popular in the places and surroundings where sensors are deployed in large numbers. They have the potential to be the first choice in localization and tracking. Pet and kids tracking are the demanded services in the cities and IoT provides very much fitting solutions to these services. IoT based localization and tracking play important roles in cellular and military

applications such as intrusion alerts, rescue and rehabilitation service during emergencies.

In addition to the advantages, there are several issues in IoT based localization and tracking. Security of users' data is a matter of concern. Security of IoT has not been developed to the required level. Attackers can easily intrude in to the IoT networks and disrupt the services. Privacy and security for localization and tracking are still issues to be solved for better reliability and trustworthiness.

V. Conclusions

In this work, we show the IoT based localization and tracking for different applications. We showed that IoT based systems are more flexible than other localization systems. These systems are also more accurate in localization and tracking. Wide spread deployment of IoT is a natural choice for localization and tracking applications. Its popularity is on the rise. However, security related aspects are still a matter of concern for these applications.

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