CHAPTER 1

INTRODUCTION

Internet of Things enabled smartphone user detection and designing of an appropriate tracking system is a major challenging task in the field of typical body area sensors. The external sensors like SPO₂ (Saturation of Peripheral Oxygen) blood pressure, Motion, Electromyography (EMG), Electrocardiogram (ECG), medical super sensor etc., are commonly used so far (Abidoye et al. 2011), while external fixed surveillance camera and Closed Circuit Television (CCTV) are highly sensitive to detect the location around the city in various places (Sanoob et al. 2016). Since tracking, and analysing the data by using the external sensor is a tedious and time-consuming task and in addition to overcome its hardware cost, in the proposed research work a Context-aware Human Tracking System (CHTS) has been designed to be used in smartphones.

The present thesis work focus on latest CHTS based IoT technology in which smartphone sensors has been used to detect user activities such as sitting, standing and walking with respect to different context and smartphone placed in different positions on user’s body. The directions tracking system can be achieved by using various low power efficient technologies such as Bluetooth Low Energy (BLE), Wireless Fidelity (Wi-Fi), Pyroelectric Infrared (PIR) sensor with STM32F407VG microcontroller which belongs to the internet of things. Finally, the performance of the proposed system is measured by various classification algorithms in order to evaluate the metrics of the system.
This chapter presents the motivations for the research work, along with their characteristics of the internet of things, applications using IoT devices, major issues and challenges in IoT. It also discusses the scope of the research work, objectives of the research, contributions and future endeavors.

1.1 MOTIVATION

Nowadays, the use of smartphones is observed to be enormously high. Thus use of automatic system for all kinds of IoT enabled product applications has been increased in the markets which help to detect and track the human location in an indoor or outdoor organization (Mahmoud & Mohamad 2016). Figure 1.1 represents the five waves of IoT. The researcher begins motivated to develop a smart system to find the location of the smartphone users with the help of internet of things technology.

![Five waves of IoT in present year](Mahmoud & Mohamad 2016)

Figure 1.1 Five waves of IoT in present year
(Mahmoud & Mohamad 2016)
1.2 INTERNET OF THINGS

Internet of Things (IoT) is the fast growing technology and prevalent in day-to-day life due to their improved use in ubiquity of smart mobile devices such as smartphones, tablets, notebooks, personal digital assistants (PDA), etc. These devices have become a part of everyone’s life in this digital world and have been utilized in various contexts, as reported in (Saeedi 2013).

With reference to this context of research, the currently available huge range of challenges has to be focused in depth so as to create a smart world. Which digital and virtual set of networks converges together with a real atmosphere to create a wonderful smart organization environment. The main aim of the IoT enabled things are "connected anywhere at any time” which has been clearly represented in Figure 1.2 represents the connection among the IoT enabled things.

![Figure 1.2 Internets of things](Mahmoud & Mohamad 2016)
Internet of things is the network of physical device/objects that are embedded with electronics, software and sensors which are then connected with different technology to sense and transmit data among things, things to human, human to things and human to human (Vermesan & Friess et al. 2014). Figure 1.3 represents the number of smartphone devices connected to an internet sources during the period from 2013 to 2019 which are expected to increase from 76 billion to 317.1 billion devices by means of either wire or wireless broadband connections. These connected devices are used in various fields such as smart health care system, smart cities, smart buildings, vehicles, portable devices and others.

![Figure 1.3 Number of smartphone devices connected from 2013 to 2019](Vermesan & Friess et al. 2014)

In the last few years, smartphones with features like sensing, processing and communication capabilities has attracted research communities in order to carry out the research work related to its various features application such as to detect and track the user’s activities signals,
positions on different contexts through smartphone, to pass real-time trip information to passengers with expected fare and trip duration, to tag digital image automatically on different contexts by sensing users in smartphone etc.,

Internet of things provides access to global users and hence customers use IoT to create business, contribute content, generate and purchase services. For these globally connected technologies like Ethernet, BLE, Wi-Fi, Zigbee, Z-waves etc., play a vital role in IoT applications as reported by (Gubbi et al. 2013).

**BLE** is the technology mainly used to enable power sensitive devices, so that it can be permanently connected to the internet. The BLE sensors will function for many years when efficient battery has been used.

**Wi-Fi** is an efficient wireless technology that has an ability to reduce the power/energy consumption and can be optimized in advance for huge data transfer using high-speed throughput.

**Ethernet** is a computer networking technology, commonly used in local area networks (LAN) and metropolitan area networks (MAN). It was commercially introduced in 1980 and was standardized in 1983 as IEEE-802.3 to support higher bit rates and longer link distances.

**Zigbee** is a low power consumption wireless technology with IEEE-802.15.4 standard, mainly used for mesh networking and IoT applications like smart home automation and remote control units, respectively.
**Z-waves** is the technology used to communicate among various devices like home automation.

In recent days, IoT enabled smartphones have more advanced features such as powerful central processing units, huge memory slots, inbuilt sensors (accelerometer, gyroscope, orientation, proximity, global positioning system etc.,) and sophisticated connectivity technology. Thus, IoT facilitates devices to achieve user-friendly characteristics such as related information, process contextual information, improved security and privacy. Due to their numerous advanced features and utilities available in the smartphone, they have become a part of the everyday life.

### 1.3 CHARACTERISTICS

IoT has eight important characteristics (Gharghan et al. 2014) which make system more powerful than usual. Each characteristic includes a set of capabilities that are essential to design CHTS.

**Intelligence** represents a high intelligent spark quality when both software and hardware, are worked together in order to help the system to experience high smartness. As an example, consider the smart vehicle driving where the high quality of smartness can be achieved only by making use of the designed software, by doing so the control towards the hardware of vehicles can be attained, thus it speaks about the intelligent spark.

**Connectivity** allows network accessibility and compatibility, which is one among the listing characteristics of IoT. Connectivity in IoT is achieved by swiping on BLE and Wi-Fi technology and thus making IoT to act as a better connectivity. Accessibility deals with accessing information into different network and its compatibility provides ability for data transfer.
**Heterogeneity** can interact with other devices or services platform through different networks.

**Dynamic Changes** is sleeping and waking up, connect or disconnect with different context of devices including location and speed. However, the number of devices involved can change dynamically.

**Sensing** is an important characteristic of IoT based applications, especially sensing related with humans. Sensing equipment in IoT have capacity to understand the specified human’s physical movement among the surrounding human. Also, as per sensing feature it has been expected that it would reflect the true physical movement of human’s involved. Sensing equipment uses analog signals from human hence it provides even more attention to the complex human postures.

**Expressing** make IoT to get interacted with the real world in a smart environment with more competent and successful manner. Hence, it could be possible to obtain user interface features in a more beautiful and gorgeous manner on the screen for better interaction with in the real world.

**Energy** is the key creation, which take part in every aspect of life. In the current advanced technology, enormous quantity of inventions that can run under batteries were created for a wide range of applications to obtain better performance efficiency than ever. But to facilitate the problem regarding the insufficient availability of energy so far, some of the energy saving measures like energy conserving, power efficiency, and charging infrastructures were integrated as a part of power intelligent system. This acts as a one of the mandatory fields for the better enhancement of the implemented technique.
Safety and Security acts as one of the vital features among the other advanced benefits. These features incorporate all creativities and it does include our personal data and our physical health security. Additionally, it also includes, securing the networks, endpoints and encrypting the data across all layers, and hence finally it can be concluded that it provides an overall security topology.

1.4 APPLICATIONS

The widespread variety of potential applications for smartphones in many fields were reported such as location-based services; updating the user’s social networks status with current activities, fall down detection for the elderly and physically handicap people, healthcare monitoring systems, etc., (Vermesan & Friess 2014). The smartphone accelerometer sensors were used to detect user’s activity, while gyroscope sensors are used to detect rotational speed along with the user’s activity and orientation sensors are used to detect the position and direction of smartphone user’s.

**Human**: IoT plays a major role in tracking both normal and abnormal human activities, in capturing its positions, with the help of smartphone placed in the different body posture. As a result of this advanced feature, IoT has its major application in human health care monitoring systems and emergency alarm applications. Example: smart watch, smartphone, activity tracker and smart glasses.

**Smart Home**: IoT supports most of the electronic devices which have been engaged in at most all the homes and thus it makes the smart home to be possible. Smart home has various advantages like smart thermostat, connected lights, smart fridge, smart door lock, energy and water use, remote control appliances, gas monitoring, safety monitoring, etc.
**Retail Environments:** IoT has been used in many stores, shopping malls and other retail shops for billing systems in which customer can do buy their products by swiping their bank cards with the money transfer device supported with IoT.

**Factories / Offices:** IoT have variety of applications in factories and offices like remote asset control, remote monitoring, smart waste management, industrial/office internet, smart attendance system, etc. Also, IoT provides more communication facilities which help employees to be in connection through they work in different workplaces. E.g., Information Technology (IT) industry, mining different operates sites, maintenance and repair, indoor and outdoor monitoring, Machine to Machine (M2M), air quality, temperature monitoring, ozone presence etc.

**Vehicles:** Automobile industry in specific has grown tremendously nowadays because of the advantage of inbuilt application which supports the feature of IoT. The application includes remote vehicle control, vehicle tracking system and many others. The best example is aviation industry, which comprise the implementation of more IoT features.

**Smart Cities:** A large number of proposals regarding the creation of smart cities have been announced recently by the Government of India, to converts selectively few cities even smarter by implementing the applications of IoT. The application includes remote traffic controls, remote check-in/out by peoples, smart parking system, smart water and waste management system, tourism, smart lightning, meter system and many others.
1.5 MAJOR ISSUES AND CHALLENGES

To develop a context-aware human tracking system, some of the technologies like BLE, Wi-Fi and PIR sensor with STM32F407VG microcontroller are used. But the data communicated using these technology and devices faces the following issues:

i. Data management

ii. Scalability

iii. Reliability

iv. Interoperability

v. Power/energy consumption

In addition, more focus should be given for some of the major challenges which are listed below (Ali et al. 2015) during the development of a context-aware human tracking system

i. Ubiquitous data collection

ii. Huge number of devices

iii. Latency

iv. Accuracy

1.6 SCOPE OF THE RESEARCH

The recent research focuses mainly on human tracking system based only on BLE, Wi-Fi, technology accomplished by smartphone sensor and PIR sensor with STM32F407VG microcontroller. These systems were implemented by using star topology in IoT.
Future scope of the human tracking system involves the development of various wireless low power and low cost innovative technology which was supported by IoT such as BLE, Adaptive Network Topology (ANT), ANT+, ZigBee, Radio Frequency for Consumer Electronics (RF4CE), Wi-Fi, Nike+, Infrared Data Association(IrDA), Near-Field Communication (NFC), IPv6, Low-power wireless Personal Area Network(6LowPAN) etc.

These systems can be implemented successfully in real time environment by using broadcast, star, mesh, scanning and point to point network topology with the help of the devices that are used in a day to day life such as smartphones, health and fitness devices, home automation, Heater, Ventilator, and Air Conditioner (HVAC), remote control system, Human Interface Devices (HID), smart meters, payment and many others in order to make the human tracking system to be more efficient and suitable for various environments in future.

1.7 OBJECTIVES

The primary objective of this research work is to design a context-aware human tracking system to locate the indoor and outdoor smartphone user’s using a latest technology such as low power and high speed data transfer BLE, Wi-Fi, either with or without using smartphone but by using external PIR sensor and BLE connected with STM32F407VG microcontroller where all of which are supported by internet of things technology.

The above type of system uses mobile devices and microcontroller kits which run under battery-power for communication purposes. As a consequence of increased use of enormous amount of energy, communication link failures and decrease in throughput results. Hence, the secondary objective of this research work was designed which includes,
i. Increase scalability and reliability  
ii. Enhance robustness (Interoperability)  
iii. Reduce the power/energy consumption  
iv. Increase Network Life Time (NLT)  

1.8 CONTRIBUTIONS  

In this research work, human tracking systems using BLE, Wi-Fi and PIR sensor with STM32F407VG microcontroller were carried out with the help of star topology which belongs to internet of things and the four contributions of this research are stated as follows:  

i. Design and development of a human tracking system for indoor smartphone users using BLE. The performance of this system has been evaluated by four different classifier such as RF with 91.42% accuracy and 8.57% error rate, Ibk with 90.55% accuracy and 9.44% error rate, j48 with 85.61% accuracy and 14.38% error rate, K* with 73.54% accuracy and 26.45% error rate. Among them, RF classifier was observed to have better accuracy and error rate than compared to other classifiers.  

ii. Design and development of a human tracking system for indoor and outdoor smartphone users using Wi-Fi. The performance of this system has been evaluated by a ten different existing classifier as discussed below; each of which has different percentage of accuracy and error rate value respectively. RF have 94.60% and 5.39%, RC have 93.82% and 6.17%, LMT have 92.32% and 7.67%, Rotation Forest have 90.76% and 9.23%, Bagging have 89.55% and 10.44%,
j48 have 89.20% and 10.79%, SC have 89.13% and 10.86%, BFTree have 88.84% and 11.15%, Ibk have 86.86% and 13.13%, REPTree have 86.64% and 13.35% respectively. Among them, RF classifier was observed to have better accuracy and error rate percentages than compared to all other classifiers.

iii. Design and development of a human tracking system either with or without using smartphone users but by using PIR sensors and BLE with STM32F407VG microcontroller. The performances of this system have been evaluated based on user’s activity signals datasets collected in an organization on daily and week wise as follows:

1. Day wise average user’s activity detected during Monday to Friday is 81.87%

2. Week wise average user’s activity detected during a month in a week day is 88.75%. In comparison, the existing system from the literature survey was observed to show 83%. As a result, production of higher user’s activity detection was observed for the present system than the existing system.

iv. Design of context-aware energy conserving algorithm for CHTS. The proposed algorithm performances have been evaluated by considering the speed of nodes Vs average residual energy, average end to end delay and number of nodes Vs average residual energy, average end to end delay and control overhead as follows:
1. Speed Vs average residual energy produced 11.1% efficiency while average end to end delay had 14.1% over the existing EEPR algorithm.

2. Number of nodes Vs average residual energy has 16.1% while averages end to end delay have 15.9%, followed by 23.7% of control overhead. Thus on comparison with existing EEPR algorithm, the proposed CECA algorithm shows better performances.

1.9 ORGANIZATION OF THE THESIS

The organization of this thesis is divided into nine chapters as follows:

Chapter 1 presents the general introduction about IoT and its motivations, characteristics, applications of the IoT devices in various fields, major issues and challenges to be focused during the design of IoT. In addition, the scope of the research, objective and contributions of this research work were clearly mentioned.

Chapter 2 discusses about the research background and literature review of the related research works with respect to the present research topic.

Chapter 3 deals with the design and overall system architecture for IoT, using various cost effective technologies like BLE, Wi-Fi and PIR sensor.

Chapter 4 contains discussion on context-aware human tracking system for indoor smartphone user’s using BLE.
Chapter 5 conveys about the design and development of a context-aware human tracking system for indoor and outdoor smartphone users using Wi-Fi.

Chapter 6 analyses about the design of a context-aware human tracking system using PIR sensor with STM32F407VG microcontroller.

Chapter 7 gives information regarding the design and development of an energy conserving algorithm for CHTS.

Chapter 8 represents the performance comparisons of various human tracking systems.

Finally, the last part of the thesis is an overview about the summary and conclusions drawn from the research investigation. Also, in Chapter 9 scopes of future work in this area of research are listed.