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A Wearable smart device to track and find the Alzheimer's patient's location

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TERTAG WISSAM - MEZHOUDI AHLEM

Dedication

I dedicate my graduation to someone I hold dearer than myself, my beloved grandmother ***Wanassa Hettab****. It is through her prayers that Allah has guided me to accomplish this achievement. May Allah protect and bless her, prolonging her life.*

I dedicate this work to the pure soul of my late grandfather, ***El-Toumi****. May Allah have mercy on him and grant him the highest paradise. I wished he could have shared in the joy of this accomplishment and success, but Allah's decree prevails.*

To the one who embodies dignity and nobility, whose name I proudly bear, my dear father ***Abd El-Madjid****. May Allah grant him a long life.*

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TERTAG WISSAM

Abstract

Alzheimer's disease is a progressive neurological disorder that affects the brain. It often begins with mild memory problems and confusion, then gradually evolves into severe memory loss. The main challenge faced by caregivers of Alzheimer's patients is the regular monitoring of The main challenge faced by caregivers of Alzheimer's patients is the regular monitoring of them and their health, which may require continuous monitoring of heart rate and, more importantly, tracking their location outside the home without relying on their caregivers.

In this main project, we propose designing and implementing a prototype for a health monitoring system to overcome the aforementioned problems. This system combines a wearable device that senses heart rate and determines the geographical location of the patient, along with an Android application for the caregiver. The data will be securely stored in a database, allowing the caregiver to track the patient's location, set parameters for a specific area, receive reminders for medical appointments, medication schedules, exercise routines, and more. Additionally, alerts will be sent if a safe zone is exceeded. The caregiver will also be able to regularly monitor the patient's heart rate and review a guide for Alzheimer's patient care.

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Keywords: *—Alzheimer's disease, Internet of Things,GPS, geolocation, WSN,Pulse sensor.*

Résumé

La maladie d'Alzheimer est un trouble neurologique progressif qui affecte le cerveau. Elle commence souvent par des problèmes légers de mémoire et de confusion, puis évolue progressivement vers une perte de mémoire sévère. Le principal défi auquel sont confrontés les aidants des patients atteints de la maladie d'Alzheimer est la surveillance régulière de leur santé, ce qui peut nécessiter une surveillance continue du rythme cardiaque et, surtout, le suivi de leur localisation en dehors du domicile sans dépendre de leurs aidants.

Dans ce projet principal, nous proposons de concevoir et de mettre en œuvre un modèle préliminaire pour un système de surveillance de la santé afin de surmonter les problèmes mentionnés précédemment. Ce système combine un dispositif portable qui détecte le rythme cardiaque et détermine la localisation géographique du patient, ainsi qu'une application Android pour l'aidant. Les données seront stockées de manière sécurisée dans une base de données, permettant à l'aidant de suivre la localisation du patient, de définir des paramètres pour une zone spécifique, de recevoir des rappels pour les rendez-vous médicaux, les horaires de prise de médicaments, les routines d'exercice, et bien plus encore. De plus, des alertes seront envoyées en cas de dépassement d'une zone de sécurité. L'aidant pourra également surveiller régulièrement le rythme cardiaque du patient et consulter un guide sur les soins aux patients atteints de la maladie d'Alzheimer. .

Mots-clés: *—Maladie d'Alzheimer, Internet des objets, GPS, géolocalisation, RCSF,Capteur de pouls.*

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Chapter 1

General Introduction

1.1 Context and problematic of this project

An increase in life expectancy contributes to the rapid increase in these numbers and is associated with an increased prevalence of chronic diseases. Alzheimer's disease, as an age-related disease and seen as a collective plight due to its impact on individuals, caregivers, families, and society, is increasing. The latest estimates indicate that the number of Alzheimer's disease cases reached 52 million cases worldwide in 2020 according to studies [22], a number that is expected to double approximately every 20 years according to [8].

This deficit represents an extremely painful condition for the patient due to forgetfulness, as it hinders their ability to perform tasks that used to seem simple but have now become challenging for them. The primary concern for their caregiver is their tendency to wander out of the house without their knowledge, in addition to outbursts of anger that make it difficult for them to consistently and easily monitor their heart rate. In our current situation, technology can assist us in various ways, including tracking devices that can monitor their location and alert the caregiver if they are in undesirable places, along with remote monitoring of their heart rate. All of this can be achieved through the utilization of the Internet of Things.

1.2 Objective of this project

The goals of my project include enhancing patient safety through technology-supported monitoring, providing peace of mind to patients and caregivers by tracking their location and heart rate, enabling a greater level of independence through assistive technology, improving comprehensive care quality through communication tools and data-driven insights, and enhancing communication channels among patients, caregivers, and healthcare providers.

1.3 Organization of the dissertation

The organization of the dissertation is as follows.

Chapter 2: Technical background

In this chapter, we will discuss general information about Alzheimer's disease and the Internet of Things (IoT), along with a brief presentation on Wireless Sensor Network (WSN). Lastly, we provided a brief overview of cloud computing.

Chapter 3: System design and analysis

The third chapter includes the design of our system and a number of diagrams explaining the functionality of our system.

Chapter 4: Implementation

The fourth chapter presents a list of development tools and the programming language used for the development of our project, along with pseudo-algorithms illustrating the system's operations. We concluded it with images showcasing our practical application aspect.

Chapter 5: Conclusion and Perspectives

This is concluding the main goal of this paper and providing a viewpoint for future work.

Chapter 2

Technical background

2.1 Introduction

Alzheimer's disease is one of the biggest problems for the population in the world, and it has become a major problem as well for the Algerian population, since its prevalence increases almost exponentially every decade. Which made us care more about this group that really needs health care and permanent monitoring. Let us take an example of a study conducted by a group of Algerian researchers on the prevalence of Alzheimer's disease in the municipality of Sidi Mohamed in the capital of Algeria:"The estimated prevalence rate for all types of dementia recorded was 4.93% among people who reached 60 years and over, 7.06% in people 70 years and over, and 13.04% in people 80 years and over"in 2022 [8].

It is excellent that technology has become a very effective element in today's world in all fields, especially in improving the quality of life of patients and more precisely, those with Alzheimer's disease.

In this chapter, we highlight the most prominent definitions and concepts of Alzheimer's disease, and we will present generalities about the technologies we have chosen to work with, namely: Internet of Things technology, Geolocalization, cloud computing, and in the end we touched on similar work.

2.2 Alzheimer's disease

In general, we will highlight the important elements about dementia, or what is known as Alzheimer's disease.

2.2.1 The definition of Alzheimer's disease

We will include some of the most interesting definitions about this disease for a better understanding :

- **Definition 1:** " Alzheimer's disease (AD) dementia refers to a particular onset and course of cognitive and functional decline associated with age together with a particular neuropathology. It was first described by Alois Alzheimer in 1906 about a patient whom he first encountered in 1901" [24].

- **Definition 2:**"Dementia(or Alzheimer's disease "AD") is defined as the presence of impairment in several domains of cognition (eg, memory, language, orientation, visuo-spatial, abstract, and executive) accompanied by functional impairment (ie, decline in ability to carry out activities of daily living). The earliest manifestation is impaired memory, which evolves over a period of a few years. With disease progression, other intellectual skills deteriorate, and behavioral problems, delusions, and a loss of control over body functions occur"[31].

So in short and in a clear sense Alzheimer's disease can be:

- Memory loss .
- Difficulty performing some gestures.
- Difficulty recognizing objects or people.
- Language disorders.

2.2.2 Risk factors for Alzheimer's disease

According to the authors of [31, 49], it was found that there are many factors that cause this disease, and we divided them into two parts according to their type:

2.2.2.1 Contributing factors

- Age: this is the main risk factor, people over 60 are the most likely to develop Alzheimer's disease.
- Sex: it affects more women than men (because they live longer than men).
- Vascular factors: Systolic hypertension, hypercholesterolemia, smoking, poorly treated diabetes, overweight and stress.

2.2.2.2 Genetic factors

- Hereditary family forms: these are the least important factors and represent less than 5% of patients suffering from Alzheimer's disease, they are linked to 3 genes(mutations):
  - APP.
  - Preselin1(PS-1).
  - Preselin2(PS-2).
- Late forms: the individual genetic factor plays an important role in the onset of the disease .They are linked to 4 genes:
  - Clusterin CLU.
  - The complement receptor CR1.
  - PICALM (related to synaptic transport).
  - APOE4 which codes for apolipoprotein E

2.2.3 The different stages of Alzheimer's disease

We know Alzheimer's disease is a neurological disorder that affects memory, thinking and behaviour. The standardized scoring algorithm classified subjects into five stages of dementia, according to the authors [13]. Each of these stages has symptoms. We will learn about the stages and their symptoms:

1. Preclinical stage:In this stage the person does not suffer from difficulties in daily life and does not show any signs of dementia, we note at this stage that it does not apply to our current study because we will only talk about people with Alzheimer's disease.

2. Mild cognitive impairment (MCI) : This stage describes the suffering of people from memory loss and the difficulty of facing problem-solving, language and decision-making. Yes, it is a situation similar to the natural deterioration of old age. These very slight cognitive defects are usually not noticed by family caregivers.

3. Early-stage: This stage is characterized by the fact that the affected person loses his memory and cognitive impairment more than before and here, and in this stage he is noticed by family and friends, so in this stage exactly the affected person:

   - He has difficulty moving around (getting lost while moving in an unknown or known place).
   - Difficulty finding the right words.
   - He often forgets names.
   - Concentration problems (difficulty planning or organizing daily activities)
   - Memory gaps (or lapses).
   - Difficulty performing familiar tasks and adjusting to society or its environment.

4. Middle-stage: Stage 4 describes profound dementia, in which persons have severe impairment in language or comprehension, inability to walk or eat without assistance, problems recognizing their family, and incontinence.

5. Late-stage:Stage 5 refers to terminal dementia, in which persons require total care and are completely uncommunicative, bedridden, vegetative, and incontinent.

2.2.4 Evolution and treatment of Alzheimer's disease

Doctors[49] have explained the development and treatment of Alzheimer's disease. First, let's clarify the progression of this disease and then discuss the treatment approach.

Alzheimer's disease generally progresses in stages, starting from mild memory loss and initial confusion to severe cognitive decline and complete dependence on care. Symptoms may also include personality changes, language problems, and sleep disorders.

Unfortunately, as previously mentioned, there is currently no cure for Alzheimer's disease. However, according to doctors, there are available treatments that can slow its progression, alleviate symptoms, and improve the quality of life for patients. The medications primarily aim to regulate neurotransmitters in the brain to enhance cognitive function.

In addition to medication, non-pharmacological methods are also utilized in the treatment of Alzheimer's disease. This may include cognitive stimulation through specific activities, behavioral therapy to manage behavioral and psychological symptoms, as well as support and assistance for patients and their caregivers.

The research on Alzheimer's disease remains actively ongoing with the hope of finding new treatments and gaining a better understanding of the underlying mechanisms of the disease. The ultimate goal is to find a way to prevent, slow down, or cure this devastating illness that affects millions of people worldwide.

2.3 An overview of the Internet of Things

In this section we provide a comprehensive overview of the Internet of Things.

2.3.1 Definition of IoT

There are many definitions of the Internet of Things and there is no fixed definition. Here we will present some of the common definitions:

- **Definition 1:**"The Internet of Things (IoT) is a network that connects and combines objects with the Internet, following protocols that ensure their communication and exchange of information across a variety of devices"[22].

- **Definition 2:** The IoT " is an emerging paradigm in the world of computer networks. It can be defined as an evolution and extension of the Internet today to include all objects and places in our environment (refrigerators, thermostats, homes, vehicles, roads, etc...)"[16].

- **Definition 3:**"The IoT is a network of networks that allows - through standardized and unified electronic identification systems and wireless mobile devices - the direct and unambiguous identification of digital entities and physical objects, and thus, the seamless retrieval, storage, transfer, and processing of data between the physical and virtual worlds"[22].

2.3.2 The functioning of the IoT

The Internet of Things is a set of connected objects that primarily operate with sensors and connected objects used to collect and exchange data. These are placed on the physical infrastructure. There are also many structures and methods to deploy the Internet of Things system. Here, sensors will transmit data that will be uploaded via a wireless network to IoT platforms. For the interconnection and operation of these different objects, the Internet must have the necessary technological systems that allow for the identification of objects and the capture, storage, processing, and transmission of data in physical environments. There are many technologies, but we will only mention the main ones here, which are RFID, WSN (Wireless Sensor Networks), and M2M (Machine-to-Machine):

- RFID : RFID system [25]is a technological solution that empowers machines and computers to automatically identify objects, capture metadata, or interact with specific targets using radio waves.

- WSN : "A WSN can be defined as a network of devices, called nodes, that can detect the environment and communicate the information collected from the monitored field (e.g., an area or a volume) via wireless links. The data is transmitted, possibly via multiple hops, to a sink (sometimes called a controller or a monitor) that can use them locally or is connected to other networks (e.g., the Internet) via a gateway. The nodes can be stationary or mobile. They can be aware of their location or not. They can be homogeneous or not"[10].

- M2M : M2M Communication technology has [35]its origins in Supervisory Control and

Data Acquisition systems, which use sensors and devices connected via wired or radio frequency networks to monitor and control industrial processes with the aid of computers.

2.3.3 The architecture of IoT

The Internet of Things has several architectures. The scheme known as the basic model is the architecture organized in three layers, which consist of: application layers, network layers, and data perception layers.

Recently, other models have been proposed, among which we mention the five-layer model, which is the most common and considered in our time. We'll explain all of this in more detail below:

2.3.3.1 Three-layer architecture

As its name suggests, it is mainly composed of three layers. We will define each layer separately based on the explanation of the authors of [4], and then show them in the figure 2.1 below:

- Perception layer: It is known as the physical layer because it contains the physical devices and the sensor layer due to the integrated sensors of physical objects. The sensors integrated into this layer collect data from devices and send this data to the network layer.

- Network layer: Responsible for connecting the perception layer to the physical layer. This layer must have communication technologies such as a secure wired or wireless connection.

- Application layer: The data received from this layer will be analyzed and processed to provide services and make decisions, then send the results from the application layer back to the perception layer through the network layer.

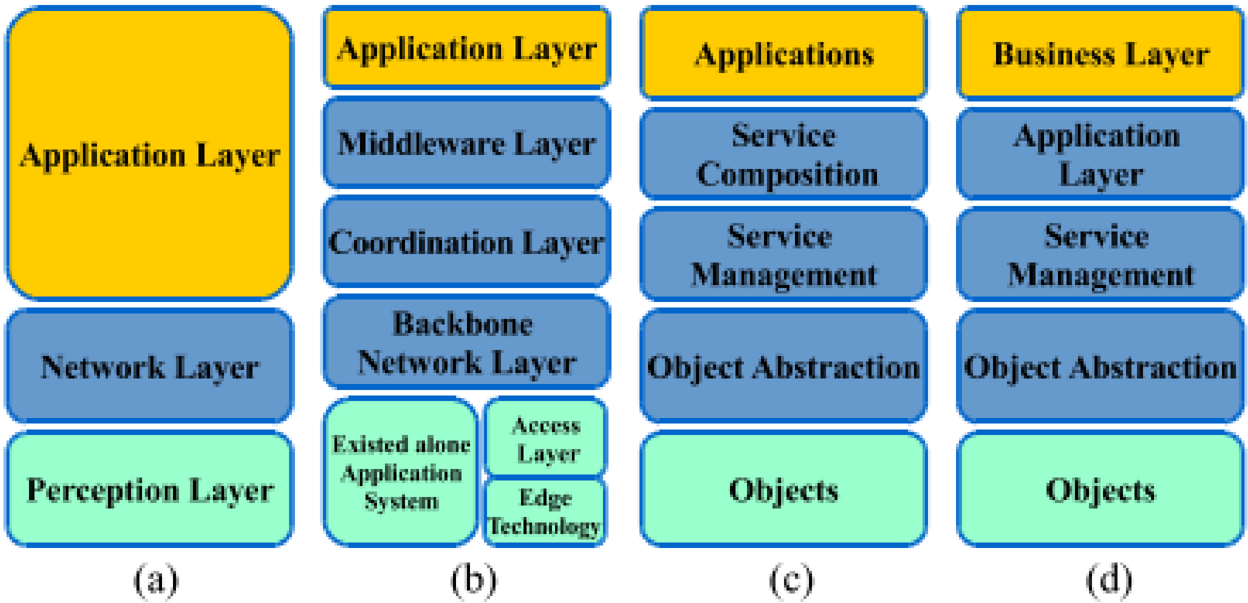

Figure 2.1: The IoT architecture. (a) Three-layer,(d) Five-layer[3]

2.3.3.2 Five-layer architecture

Now we will get acquainted with the IoT architecture consisting of 5 layers in a row, according to what was stated in the article [3], shown in fig2.1:

- Object layer: The first layer, Objects (devices) or the perception layer, represents the physical sensors of the IoT that aim to collect and process information. This layer includes sensors and actuators to perform different functionalities such as location, temperature, weight, motion, vibrations, acceleration, humidity, etc. Standard Plug-And-Play mechanisms must be used by the perception layer to configure heterogeneous objects. The perception layer digitizes and transfers data to the Object Abstraction layer through secure channels. Big data created by IoT is thrown at this layer.

- Object Abstraction Layer (Network Layer): The Object Abstraction Layer (Network Layer): The object abstraction layer transfers the data produced by the Object Layer to the service management layer via secure channels. Data can be transferred via various technologies such as 3G, GSM, UMTS, WiFi, Bluetooth Low Energy, infrared, ZigBee, etc. In addition, other functions such as Cloud Computing and data management processes are handled in this layer.

- Service Management Layer (Middleware Layer) : The service management layer or middleware associates a service with its requester based on addresses and names. This layer allows IoT application programmers to work with heterogeneous objects without regard for a specific hardware platform. In addition, this layer processes the received data, makes decisions, and delivers the required services on network protocols.

- Application layer The application layer provides the services requested by clients. For example, the application layer can provide air temperature and humidity measurements to the client who requests this data. The importance of this layer for IoT is that it has the ability to provide high-quality intelligent services to meet customer needs. The application layer covers many vertical markets such as smart homes, smart buildings, transportation, industrial automation, and smart healthcare.

- Business layer : This layer manages the activities and services of the IoT system. The responsibilities of this layer are to build a business model, charts, diagrams, etc. based on the data received from the Application layer. It is also supposed to design, analyze, implement, evaluate, monitor, and develop IoT system-related elements. This layer enables support for data-driven decision-making processes. Additionally, monitoring and managing the four underlying layers are accomplished at this level. Moreover, this layer compares the output of each layer with the expected output to enhance services and maintain user privacy.

2.3.4 The elements of IoT

The basic elements of the Internet of Things help to better understand the true meaning and function of the Internet of Things. In this section, we will introduce six key elements that are required according to the authors of[33], (namely: definition, detection, communication, computing, services, and semantics) and are essential for providing IoT functionality. We will see them in the figure 2.2 below:

- Identification : Identification plays a crucial role in the advancement of IoT, as it enables accurate recognition of objects and facilitates the customization of services based on their specific requirements. Numerous methods for identification have been developed, including Electronic Product Codes (EPC) and Ubiquitous Code (uCode). The process of object identification involves assigning a distinct name or designation, while addressing involves assigning an IP address for seamless communication within the network. Presently, addressing methods encompass widely used IPv4, IPv6, and 6LoWPAN, which incorporates compression techniques for IPv6 headers. The extensive addressing space offered by IPv6 is expected to cater to all addressing requirements of the IoT ecosystem.

- Sensing : Within the realm of IoT, sensing pertains to the collection of data from the surrounding environment, which is then transmitted to a database located either remotely, locally, or in a cloud-based system. Examples of IoT sensors include smart sensors, actuators, and wearable sensors, among others. These sensors serve the purpose of capturing relevant information and facilitating the seamless integration of physical objects into the IoT network.

- Communication : Communication serves as a crucial component of all IoT devices, considering the inherent limitations of the connected "things" themselves, such as limited battery life or restricted data transmission range. To overcome these challenges, various protocols are commonly employed, including WiFi, ZigBee, GSM, GPRS, UMTS, 3G, LTE, and 5G, among others. In 2012, the IEEE introduced the IEEE 802.15.4e standard as an enhancement to the previous 802.15.4 standard, aiming to address the evolving requirements of embedded industrial applications.

  Proximity communication technologies like RFID, NFC, and Beacons (Bluetooth Low Energy) are also utilized in IoT systems. Authors have proposed a collision window tree protocol without memory (CwT+) for radio frequency identification (RFID) anti-collision, demonstrating superior performance compared to earlier protocols. They have also presented a cost-effective and adaptable NFC tag, enabling seamless communication between everyday objects, smartphones, and computers, thereby facilitating their integration into the IoT ecosystem. The authors highlight that their NFC design adheres to the essential regulatory standards, even with relaxed 5-micron design rules, thanks to optimized design topologies.

Bluetooth 4.2, equipped with features suitable for low-power communication technologies in the IoT, including Bluetooth Low Energy, is extensively utilized within 6LoWPAN networks. Its capabilities make it an ideal choice for enabling efficient and energy-saving communication within IoT deployments.

- Computation : The deployment of IoT involves utilizing various hardware platform applications such as Arduino, Intel Galileo, Raspberry Pi, and ESP8266. These platforms play a significant role in enabling the functionality of IoT devices. Additionally, cloud computing platforms play a crucial role in the IoT paradigm by offering resources for storing and processing real-time data. These cloud platforms provide the necessary infrastructure to handle the large volumes of data generated by IoT devices, facilitating efficient data storage and analysis.

- Services : IoT services can be categorized into various types, including identity-related services, information aggregation services, collaborative services, and ubiquitous services. Identity-related services primarily revolve around the identification of objects within the IoT ecosystem. On the other hand, information aggregation services gather and condense sensory data, forwarding it to the central application for further processing and analysis.

  Collaborative services play a crucial role in leveraging the accumulated data to make informed decisions and take appropriate actions. These services enable the transformation of collected information into actionable insights, allowing for effective responses and adaptive behavior within the IoT environment.

  Ubiquitous services aim to provide collaborative-aware functionality that is readily accessible anytime and anywhere to all individuals involved. By ensuring widespread availability and seamless accessibility, ubiquitous services enable the delivery of collaborative-aware capabilities to a wide range of users and devices, enhancing the overall effectiveness and impact of the IoT system.

- Semantic : In the context of IoT, the term "semantic" refers to the capacity to extract meaningful knowledge from machines in order to deliver the necessary services. This is achieved by leveraging various modeling resources and information. To enable semantic capabilities, technologies such as the Resource Description Framework (RDF) and the Web Ontology Language (OWL) are commonly employed. These Semantic Web technologies provide a framework for representing and organizing data in a structured manner, facilitating the extraction of valuable insights and enabling the provision of contextually relevant services within the IoT ecosystem.

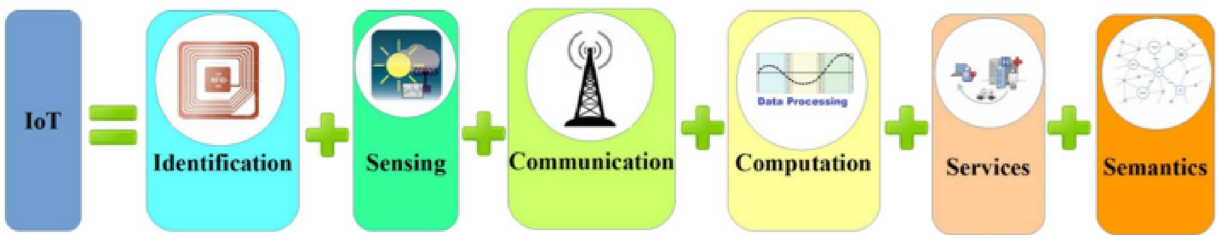

Figure 2.2: The IoT elements.[3]

2.4 An overview of Wireless Sensor Networks

Wireless Sensor Networks(WSNs) generally consist of a large number of small, fixed or mobile sensor nodes, often randomly deployed in a hostile, isolated environment. Also in this section, we present the most prominent headlines related to WSN.

2.4.1 Definition of Wireless Sensor Networks

We offer two definitions to clarify the meaning:

- **Definition 1:** “Wireless sensor networks are composed of nodes deployed in large numbers to collect and transmit environmental data to one or more collection points, in an autonomous manner”[11].

- **Definition 2:** “Wireless sensor networks are composed of nodes deployed in large numbers to collect and transmit environmental data to one or more collection points, in an autonomous manner”[29].

2.4.2 Sensor nodes

According to [28], sensor nodes play an important role in transmitting data from one node to another specified nodes within their wide range.

Regarding the scientific thesis [42], we will now provide a detailed definition of the sensor node, along with its details and areas of application.

2.4.2.1 Definition of a sensor node

Is a device that translates parameters or events in the physical world into signals that can be measured and analyzed.

2.4.2.2 Details of the sensor node (its components)

Usually, and as is common, the sensor node is composed of four basic components necessary for its formation. We will now present the definitions of these units :

- Acquisition unit The unit of acquisition is usually composed of two sub-units: sensors and analog-to-digital converters (ADCs). The sensors obtain digital measurements on environmental parameters and transform them into analog signals. The ADCs convert these analog signals into digital signals.

- Processing unit : As its name suggests, this unit is responsible for all the processing that a sensor node must perform. It includes two interfaces: one interface with the acquisition unit and another with the transmission module. The processing unit controls the procedures allowing the sensor node to perform tasks of data acquisition and storage, through a microcontroller (a simple processor) and a memory limited to a few kilobytes.

- The communication unit (Transceiver: transmitter-receiver): responsible for all communications via a radio communication medium that connects the node to the network.

- Battery : powers the acquisition, processing, and communication units.

  The figure shows the components of the sensor node:2.3:

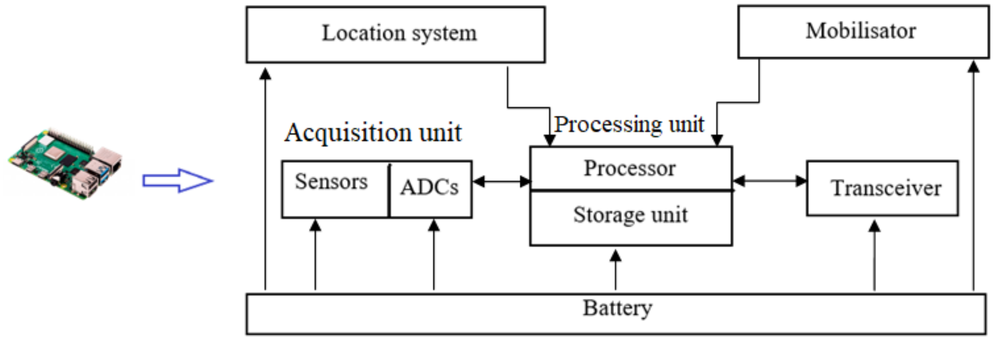

Figure 2.3: Sensor Node Components)[42]

2.4.2.3 Domain of the sensor node

The sensor nodes are very popular today and continue to grow and develop more and more. Speaking of its widespread use, we will mention some of its different fields in everyday life. Among them are military, agricultural, healthcare, industrial, and so on.

2.4.3 The transmission technologies in WSN

The wireless communication in sensor networks enables the exchange of information. This is very important. RCSF transmission technologies support several types of these technologies. We will highlight some of the most common examples taken from th article[12]:

1. Wi-Fi : "The IEEE 802.11 network is a specification for wireless local area networks (WLANs). In its low-band mode, IEEE 802.11(b, g, n) transmits data from 11 Mbps up to 54 Mbps and ranges up to 32 meters indoors and 95 meters outdoors. The IEEE 802.11n standard uses twice the radio spectrum compared to 802.11a or 802.11g. However, IEEE 802.11a, c transmission data rates are up to Gbps and can exceed the range of more than twice that of b and g technologies. Low-band Wi-Fi transmits in the ISM 2.4 GHz band while high-band transmits in the 5 GHz band. A digital modulation technique of BPSK and QPSK is used to transmit data up to 54 Mbps, and each ISM band channel has a width of 22 MHz and overlaps. Two channels whose channel numbers differ by five or more do not overlap. The Wi-Fi's enhanced isotropic radiated power (EIRP) is limited to 20 dBm (100 mW)".

2. Bluetooth : "The IEEE 802.15.1 standard is a proprietary open wireless technology stan-

dard for exchanging data over short distances. It uses the ISM band of short wavelength radio transmission in the 2400-2480 MHz band. It is desirable for the wireless personal area network (WPAN) to be adopted only to replace cable technology. Bluetooth radio adopts frequency-hopping spread spectrum (FHSS) technology. It occupies the entire ISM band, thereby using 79 channels with each channel at 1 MHz. The GFSK, EDR, /4-DQPSK, and 8 DPSK modulation formats are used in Bluetooth technology. The transmission distance of this technology varies with the transmission power. A class 1 device with an output power of 100 mW can transmit up to 100 meters, while a device with an output power of 25 mW can reach up to 10 meters".

3. ZigBee : "This specification has been adopted for low-cost, low-power digital radios and has found application in areas such as home automation, telecommunications services, healthcare, and remote control, to name a few. Similar to Wi-Fi and Bluetooth technologies, ZigBee also operates in the ISM radio band. It has a data transmission rate of 250 Kbps. The ZigBee technology (IEEE 802.15.4) specifies the physical and medium access control layers for low-rate wireless PAN and transmits up to 10 meters. Sixteen channels are defined for this specification in the 2.4 GHz band but with a narrower band of 2 MHz and they do not overlap either. Thus, up to sixteen ZigBee networks can coexist in the same area and at the same time. A newer version of ZigBee supports frequency hopping in the "ZigBee Pro" standard. This allows a ZigBee PAN to move from one channel to another if an overload occurs in the old channel. The communication model requires it to distribute work among many different devices residing in individual ZigBee nodes, which in turn form a network".

2.5 GPS and geolocation

Through the word "geolocation", we can understand that it is a technology (not a modern technology as some people think) for directions and paths. To learn about this technology, follow us and we will explain it to you at the moment:

2.5.1 Definition of geolocation

Geolocation consists of locating a resource or an individual on a map or a plan using their geographical coordinates (longitude, latitude, altitude). This operation is executed as reported by authors [20] is carried out using a device capable of being located, such as a GPS receiver or a satellite positioning system. The recorded positions can be stored within the device and extracted later, or transmitted in real-time to a geolocation software platform. Real-time transmission requires a device equipped with a telecommunication means such as GSM, GPRS, UMTS, radio or satellite, allowing it to send positions at regular intervals. This allows the position of the device to be displayed on a map through a geolocation platform, most often accessible from the internet.

2.5.2 Geolocation techniques

There are many geolocation technologies. Each of them has specific properties and a very particular mode of action. Here we will present each of the most important geolocation technologies:

2.5.2.1 Satellite geolocation

Satellite geolocation consists of calculating By interpretation of the authors [1] , through the signals exchanged between a constellation of satellites intended for this purpose and the receiver equipped with a compatible chip. The measurement of the signal travel time allows the identification of the longitude, latitude, and altitude of the observed object, with a precision that can reach up to 5 meters and can then be physically represented on a map.

The most well-known satellite positioning network is GPS (Global Positioning System). This technique is very precise as it allows for localization within 15 meters (100 meters at most). The system is based on measuring the distance between the receiver and the orbiting satellite, using the concept that distance = time * speed. The speed corresponds to the velocity of the transmitted waves, which is very close to that of light = 3108 m/s. The difficulty lies in determining the precise time. Indeed, we are dealing with very small times to detect a difference of one kilometer, a difference that is significant compared to the precision of the GPS system. The receiver must be able to measure a time difference equal to 1/300,000 = 3.3310-6, or about 3 millionths of a second. The satellite and the receiver generate a unique pseudo-random frame at the same time. The receiver receives this same frame but with a time delay(shown in the figure2.4).

There are many satellite positioning systems out there, the authors [1] explain it through these points:

- Glonass system (GLObal'naya Navigatsionnaya Sputnikovaya Sistema).
- Galileo system.
- Beidu system.
- EGNOS system (European Geostationary Navigation Overlay Service).
- MEOSAR system(Medium Earth Orbit Search And Rescue).

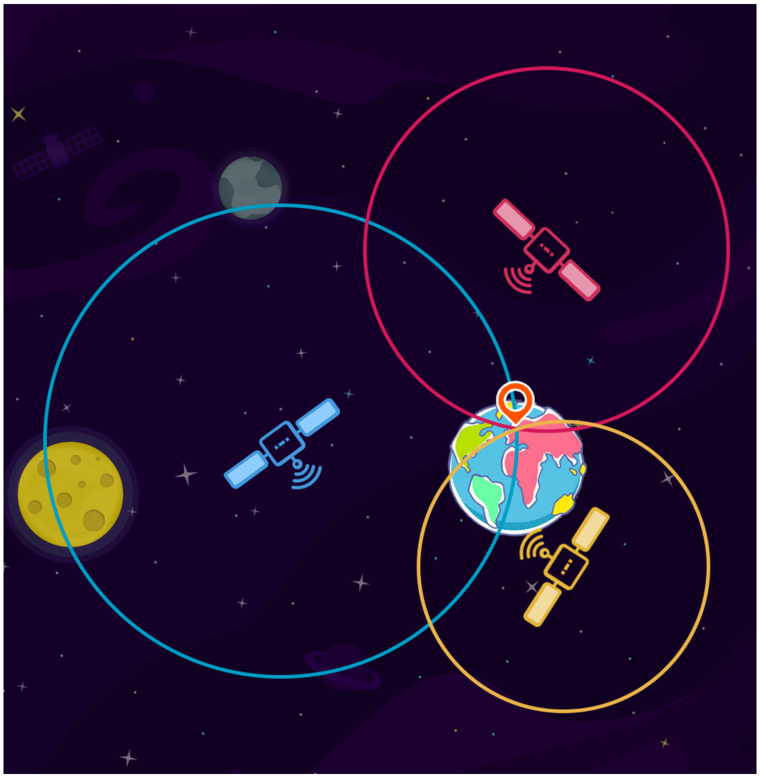

Figure 2.4: Satellite geolocation[1]

2.5.2.2 Geolocation by GSM

Geolocation by GSM is made possible by GSM mobile phone technology according to the authors of [14], and allows precise geolocation of a GSM terminal (mobile phone) to be determined with a certain accuracy using information extracted from the GSM antennas to which the terminal is connected. There are several techniques to perform this operation:

1. **Enhanced Observed Time Difference(E-OTD):**This technique is similar to that of GPS, but it is used in cellular networks. Base stations send a signal received by both the mobile and a special antenna located at a fixed and known distance from each base station[43]. To calculate the distance by triangulation, one of the previous techniques, such as TOA, is used between the base stations and the special antenna, which allows a correction factor based on the actual distance to be derived. The mobile also calculates its position by triangulation and improves accuracy through the calculation performed by the special antenna. This method can achieve an accuracy of 25 meters, but it requires significant investment to install a special antenna and modify mobile software.Look at the figure2.5.

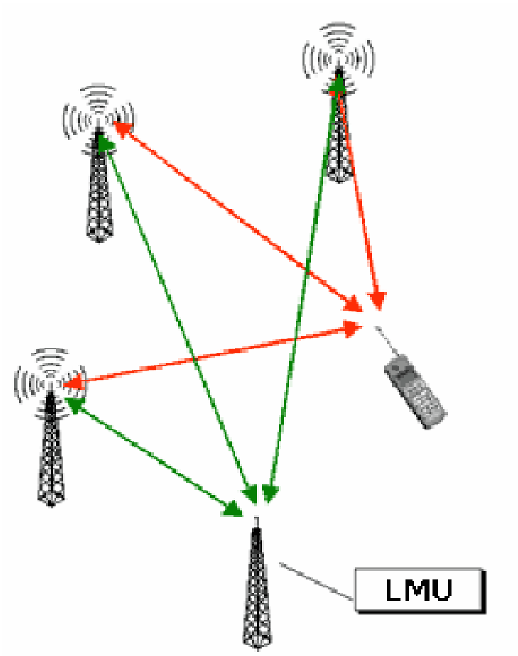

Figure 2.5: Positioning by E-OTD[43]

2. **Time Of Arrival (TOA):**The TOA method calculates the time required for data transmis-

sion between the mobile station and the base station (BTS), and vice versa according to [34]. Given that the propagation time of radio waves is known, it is possible to estimate the distance between the mobile station and the base station. This technique allows the user to be located within a circle centered on the base station and with a radius equal to the distance between the mobile station and the base station. This system can achieve resolutions of 125 meters.Look at the figure2.6.

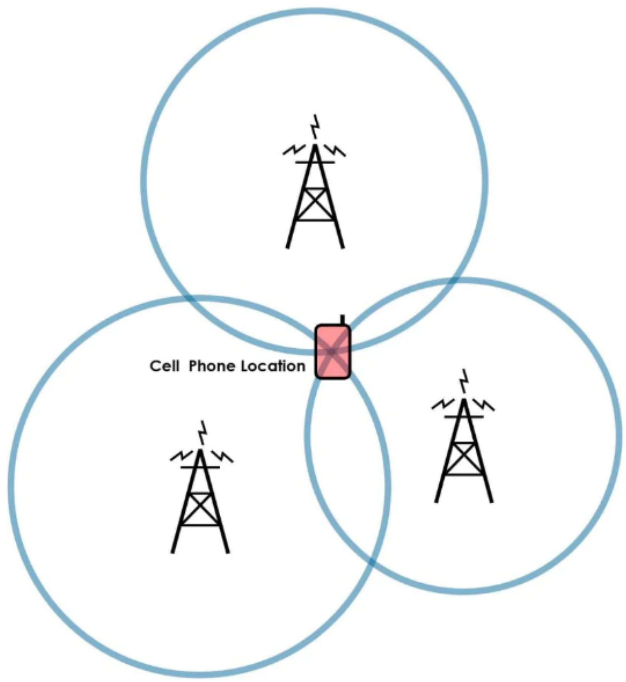

Figure 2.6: Positioning by TOA[34]

3. **Angle Of Arrival (AOA):** By performing triangulation from the angle of arrival of signals from at least two base stations, it is possible to determine the position of the mobile station in the manner of [41]. However, this method is not very effective in urban areas due to the need for a clear environment to accurately measure the angles of arrival of signals.

2.5.2.3 The wifi geolocation

Geolocation by Wifi works similarly to geolocation by GSM, by detecting nearby Wifi access points of the geolocated device. Wifi-enabled devices can also use this method by using the MAC addresses of the detected Wifi access points. All this according to[30] and there are databases that list a large number of Wifi access points as well as their geographic location, either owned by private companies or shared by communities for free. These databases are built using the WarDriving method, which involves driving through city streets with a laptop equipped with Wifi and a GPS receiver to list as many Wifi access points as possible.

2.5.2.4 Geolocation by IP address (on the internet)

The geolocation technique based on IP address allows determining the geographical position of a computer or any other device connected to the Internet. IP addresses are assigned by the IANA4, an organization that distributes available IP addresses to requesting countries, which allows for precise documentation of assignments[45]. Therefore, it is possible to easily locate a device by knowing its IP address and even obtain precision down to the city based on the distribution of IP addresses performed by Internet service providers. Several geolocation websites use this IP addressing technique.

2.5.2.5 RFID-based geolocation

Radio-frequency identification (RFID), is a method for storing and retrieving data remotely using geolocation chips, also known as "tags", equipped with an antenna capable of transmitting a unique serial number to readers. The tags can take the form of radio labels, which are miniature semiconductors. This technology allows for the identification of an object, tracking its movements and obtaining its characteristics from a distance thanks to the attached or embedded tag[46]. For this purpose, a series of RFID readers equipped with different antennas are positioned to cover the desired area. The area is then divided into cells, the size of which varies according to the number and power of the deployed readers. When the object equipped with an active radio tag (RFID tag) is located in one of these zones, the system is able to calculate its position based on the number of readers that detect the tag and deduce the approximate position of the object with reference to the real-time established cutting scheme.

The RFID technology has many applications in various fields such as:

- Supply chain management.
- The localization and tracking of goods.
- Mobile payments.
- Theft detection.
- The localization and identification of individuals.
- Its use extends to transportation and other areas such as defense, healthcare, security, and access control. It allows for precise indoor and outdoor geolocation. However, its high cost and limited detection zone are major disadvantages.

2.5.3 The geolocation services

Geolocation can be important or even essential in many fields of activity. The objectives and purposes vary according to these fields, but thanks to its great adaptability,geolocation meets the diverse expectations of a large number of professions[44].So among his services:

- Keep in touch.
- Surveillance, Security.
- Passenger transport.
- Tracking of mobile workers.

2.5.4 Satellite-based geolocation system

2.5.4.1 GPS systeme

The United States Department of Defense designed the GPS system for military purposes, but it quickly became apparent that the signals transmitted by the satellites could be captured and freely exploited[18]. Thus, as soon as a receiver was equipped with the necessary electronic circuits and software to process the received information, it was possible to determine its position on the surface of the earth with unprecedented precision. With such a receiver, a person can locate and orient themselves on land, at sea, in the air, or in the near-earth space.

2.5.4.2 Operating principles of GPS

The observer who has a GPS receiver is able to receive information from all visible satellites in the constellation. The received data is then used by the receiver to determine a position relative to a reference system called ECEF (Earth Centered, Earth Fixed),look at the fig2.7:

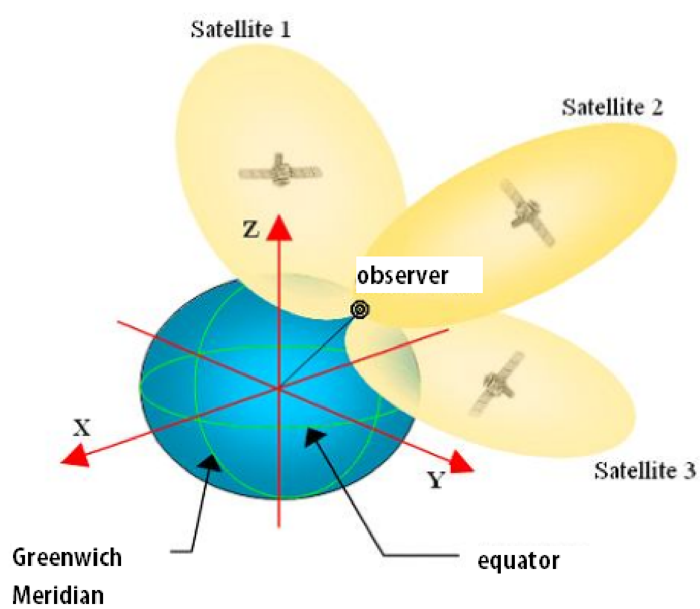

Figure 2.7: How GPS Works[20]

The information sent by each satellite includes, among other things: the diverse expectations of a large number of professions.

- The exact position of the satellite in the ECEF system.
- The exact time the signal was sent.

The GPS receiver analyzes the time difference between the transmission and reception of the signal, and then uses a calculation to determine its distance from the various satellites[20]. The position of the receiver is then determined at the intersection of all spheres whose radius is equal to the distance between the satellite and the receiver.Note the following figure 2.8:

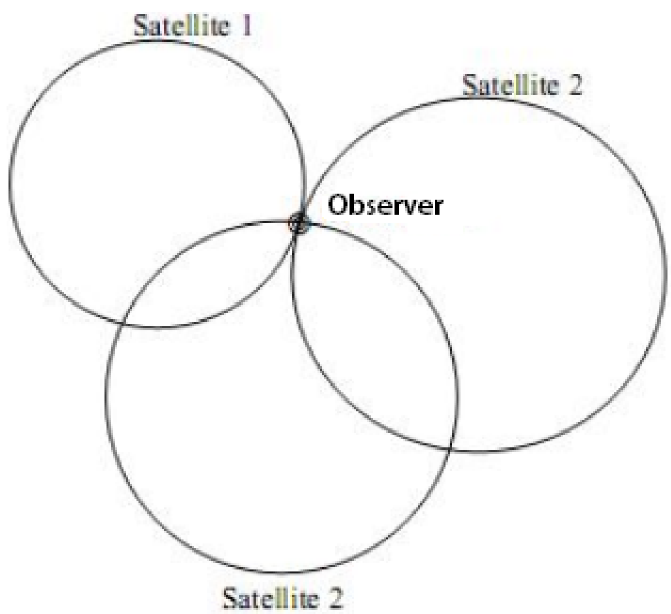

Figure 2.8: Positioning of the observer at the intersection of the 3 satellites[20]

But things not being perfect, reality will be quite different. Our observer will actually be somewhere in the common area to the three satellites, see at the picture 2.9:

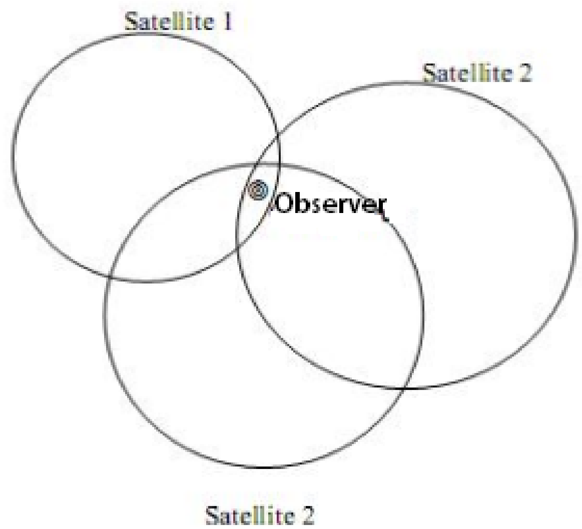

Figure 2.9: Positioning of the observer in the common area of the 3 satellites[20]

2.5.4.3 Composition of the GPS system

When we talk about GPS, we often tend to think only of the device that allows us to determine our position. However, it is important to note that the GPS system consists of three distinct elements, also called segments[32]. The first segment is made up of satellites orbiting the Earth and is called the "space segment". The second segment, called the "control segment", includes control stations responsible for monitoring and correcting satellite signals. Finally, the last segment, called the "user segment", includes GPS receivers that we use to determine our position.

1. **space segment:** The spatial segment includes all the orbital elements of the positioning system, including the platforms, GPS signals, and navigation messages,this is according to [48].It consists of a constellation of 24 satellites, in quasi-circular orbit around the Earth at an altitude of approximately 20,000 km. These satellites are distributed on six orbital planes inclined at 55° to the equator, thus ensuring permanent visibility of at least six satellites from any point on the globe. The minimum lifetime of the system is 7 years (see at the fig 2.10):

Figure 2.10: space segment[48]

2. **control segment:** The control segment is composed of five ground stations with the following missions:

   - The process of registering signals and predicting ephemeris.
   - Observation of oscillator behavior, calculation of synchronization parameters and clock drift.
   - Collection of meteorological information.
   - The control segment transmits the necessary information for composing the navigation message to the satellites.

   The authors explain in [23], that by combining the efforts of measurement stations around the world with the interventions of GPS system control stations, the IGS (International GPS Service for Geodynamics) is able to provide highly accurate ephemeris, allowing for very precise orbitography calculations.

3. **user segment:** The user segment consists of receivers that have been designed to decode the signal transmitted by the satellites as well as the methods of measuring absolute or relative position,figure 2.11 shows user segment.

   There are several types of GPS receivers available to users, which can be classified into two categories according to article [23]: consumer-grade devices and professional-grade devices. Consumer-grade devices typically use a pseudo-range measurement frequency (L1) and can receive differential corrections from a fixed transmitting station. Professional-grade devices can operate on two frequencies and measure both pseudo-ranges and phases, with costs ranging from €150 to over €15,000 depending on precision needs.

Figure 2.11: user segment

2.5.4.4 Applications of a GPS

There are many uses for a GPS tracker, both for personal and professional applications. For individuals, it can be used for the location of sick, lonely, or vulnerable people, or for the geolocation of animals. For professionals, geolocation allows for increased productivity, fuel and communication savings, as well as vehicle safety. Geolocation applications are mainly used to track a fleet of trucks or passenger transport vehicles according to [36], to improve fleet management and responsiveness in case of incidents.

2.5.4.5 Disadvantages of GPS

The GPS also has some drawbacks,Among those presented by the authors of [23],We mention:

- It is an American system over which users have no control or legal guarantee of proper functioning.
- The geometry of the satellites can affect the quality of the location. When the satellites are located at relatively wide angles, ideal satellite geometry exists. However, the geometry is weak when the satellites are aligned or in a tight group.

- Multipath is a source of location errors that occur when the GPS signal is reflected by objects before reaching the receiver. This increases the signal's travel time and can cause location errors.

2.5.4.6 Advantages of GPS

GPS features by[36] include:

- The ability to obtain an absolute position that does not depend on initial conditions.
- Long-term accuracy without drift.
- The ability to be operational at any time, without the need for special conditions such as support, orientation, or a particular temperature.
- Affordable cost for simple receivers, which is now accessible to consumer vehicles, with prices ranging from 12,500.00 DA to 45,000.00 DA in Algeria for GPS devices.

2.6 Cloud Computing

Cloud Computing is an extremely flexible environment for building new systems and applications and even integrating additional capabilities or new features into existing systems.

2.6.1 What is Cloud Computing?

Cloud computing is a "term used to describe both a platform and a type of application. A cloud computing platform dynamically provisions, configures, reconfigures, and deprovisions servers as per requirement. The servers in the cloud can be physical machines or virtual machines. Advanced clouds typically include other computing resources such as Storage Area Networks (SANs), network equipment, firewalls, and other security devices. Cloud computing also describes applications that are extended to be accessible via the Internet. These cloud applications use large data centers and powerful servers that host web applications and web services. Anyone with an appropriate internet connection and a standard browser can access a cloud application"[9].

2.6.2 Definition of Cloud Computing

A cloud is a pool of virtualized computing resources. Authors in [39] propose a cloud can:

- Host a variety of different workloads, including batch-type back-end tasks and interactive applications for users.
- Enable rapid deployment and evolution of workloads through fast provisioning of virtual or physical machines.
- Support redundant, self-recovering, and highly scalable programming models that allow workloads to recover from many inevitable hardware/software failures.
- Monitor resource usage in real-time to allow for reallocation of allocations as needed.

2.6.3 Categories of Cloud Computing

There are various dimensions to classify cloud computing, two commonly used categories are: service boundary and service type.So:

- **From a service boundary perspective:** cloud computing can be classified into public cloud, private cloud, and hybrid cloud. Public cloud refers to services provided to external parties. Companies build and operate their own private cloud. The hybrid cloud shares resources between the public cloud and the private cloud via a secure network. Virtual private cloud (VPC) services published by Google and Amazon are examples of a hybrid cloud.
- **From the point of view of the type of service:** cloud computing can be classified as infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS). SaaS provides services to end-users, while IaaS and PaaS provide services to ISVs and developers, leaving room for third-party application developers.

2.7 Related works

The follow-up of unfit people (children or patients who are affected by our Alzheimer's disease project because they are more likely to lose due to memory loss) has attracted the attention of a number of researchers and inventors around the world. . Previous works include:

- “Design and Implementation of an Android Wearable Smart Locator Band for People with Autism, Dementia and Alzheimer’s Disease”[19] is a smart belt combined with an Android SMS Receiver application that provides SMS alert service. This service includes the current latitude and altitude of the patient’s location when the exact GPS location is not valid for the wearer. The device sends the SMS alert to the Android phone, and the "SMS Receiver" is opened directly. If the received SMS is opened with an active internet connection, the location will be shown on the Google Map. In addition, the device has a talking feature but lacks medication timing notifications, the most important of which is when a sponsor is looking for a patient they won’t be able to find... . The focus of our project is on what is most important to the sponsor and patient such as reminders, alerts, tracking, and designing an affordable bracelet that fits the patient’s needs.

- In the paper[37] the “ALZ Caretaker” app provides a host of features, including GPS-based tracking of patient steps, and reminders to take medications and take meals. It is necessary to install this application on both the sponsor’s and the patient’s smartphones. The sponsor tracks the patient with GPS technology. Despite the valuable insights gained from these studies, there may be some challenges to using the application interface for the patient, in addition, holding the phone may be Mobile with them is expensive.

- Centered around children with autism, this work consists of a “wearable cap with solar panels, a switching impulse and a DC battery”[2] linked to an "Android Health monitoring and tracking App". This work includes sending the device regular messages between an interval of an hour or two. This message contains the natural information of the child, which is the body temperature, heart rate and coordinates of its location, while alerts are sent after an interval of 10 minutes in the event that it exceeds a specific area or if there is a change In the case of his body temperature or heartbeat to the Android phone, messages are sent by GSM and the location is determined by GPS technology.

- In the “iCare” project[5] , an Apple Smart Watch was designed for Alzheimer’s patients with an iOS application on the caregiver’s iPhone. These two parts (the smart watch and the application) are connected to the Internet, taking advantage of the concept of the Internet of

Things(IoT). This application allows them to track their patients on a map. Google via the GPS feature on the device, displaying the heart rate in the form of a graphic curve, a list of to-do reminders such as medical appointments, and finally a special section for information about Alzheimer's disease. This project lacks notification alerts exceeding a specific area and it is not available to most people (iOS system) because Android dominates the global market and it is a basic system.

- "Smart Location Tracking System for Dementia Patients"[27]proposes a system helpful in real-time tracking of dementia patient and notifying the caretaker about the patient's location through the global coordinates he is getting from patient's device. The app will automatically detect the message containing global location coordinates and a message titled 'location detected' is displayed on the notification bar. When caretaker opens that notification, he will be directed to Google map and the exact location of patient is displayed. In case, if caretaker is busy and unable to see the incoming message from patient's device, then also he/she can keep track of the patient. The Android app is having a facility to keep record of locations. Records contain patients name, date of incoming messages and time.

After providing a summary of some of the above-mentioned similar works.

Table 2.1 below illustrates a comparison between the related work and our work (which aims to monitor the location of individuals with autism, dementia, or Alzheimer's).

Ref	Project name	GPS tech	GSM tech	IoT	Reminder	Care guide	Platforms supported	Notification /Alarm geo-fence	User guide	Support Ar lgge
[19]	smart locator wrist band	Yes	Yes	No	No	No	Android	Yes/Yes	No	No
[37]	ALZ care-taker	Yes	No	No	Yes	No	Android	Yes/No	No	No
[2]	Wear-Cam	Yes	Yes	No	No	No	Android	Yes/Yes	No	No
[5]	iCare	Yes	No	Yes	Yes	Yes	IOS	Yes/No	No	Yes
[27]	Wearable device as a watch	Yes	Yes	No	No	No	Android	Yes/No	No	No
	Our Project	Yes	Yes	Yes	Yes	Yes	Android	Yes/Yes	Yes	Yes

Table 2.1: Comparison of related works.

2.8 Conclusion

Medical research is still making great progress, but despite this progress, until now there is no known cure for Alzheimer's disease, so it is necessary to find solutions to help people with this disease adapt to their society and environment and feel safe and independent with the reassurance of their families or friends.

During this chapter, we have described the basic concepts with simple and varied definitions to remove the ambiguity, that centered around Alzheimer's disease, Internet of Things technology with the promising technology of wireless sensor network, geolocalization, and cloud computing. We also presented some similar works related to the subject of our research.

In the next chapter, we will present the topic of our research represented in the solution that concerns this group in need of health care and monitoring "It is a smart device worn by an Alzheimer's patient with an application for his sponsor".

Chapter 3

System design and analysis

3.1 Introduction

As we mentioned in the last chapter, among the biggest problems that an Alzheimer's patient faces is getting lost while moving somewhere as a result of memory loss and other problems. How will we help this patient? And how do we reduce the burden on his sponsor?

That is why we consider this part to be the most important, due to its focus on the studies that we conducted and needs analysis as well as system design.

In this chapter, we will introduce the specification, analysis and design of our system through several structures including general structures, and UML (Unified Modeling Language) standard language for modeling our system.

3.2 Motivation

Today, we notice that technology has become a crucial factor, especially in the care sector, in assisting and facilitating healthcare and monitoring. When talking about technology, we mention the ones that have truly helped us in achieving our project, namely the Internet of Things (IoT) technology, along with cloud computing technology...

Without neglecting sensors, which have become affordable.

3.3 System design

Design is an important stage in creating a project. To illustrate our work, we constructed two general structures that explain it:

3.3.1 General architecture

We have designed and implemented a wearable smart device capable of tracking and detecting the location of the wearer, along with measuring their heart rate. This device is connected to the Internet of Things (IoT) and linked to an application that enables remote caregiving and real-time monitoring of the patient. This will provide reassurance and reliability for the caregiver, as well as a sense of security for the wearer.

Now we show you a simplified illustration that explains our project3.1:

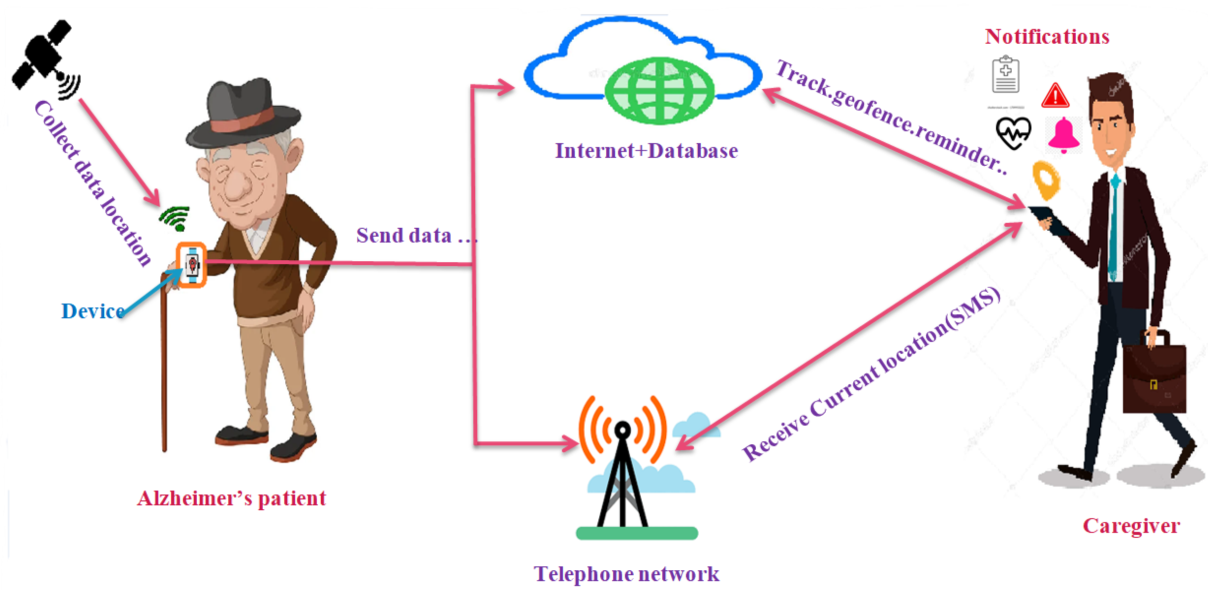

Figure 3.1: Illustration expresses our project on the ground

3.3.1.1 Architecture of the patient site capture process

Regarding this structure, it shows us the sum of the components connected to each other, in the form of a simple and comprehensive architecture to capture the patient's location (latitude and longitude) and send it over wifi for storage and over the GSM network in the form of a text message with a Google Maps link. As shown in the following figure 3.3:

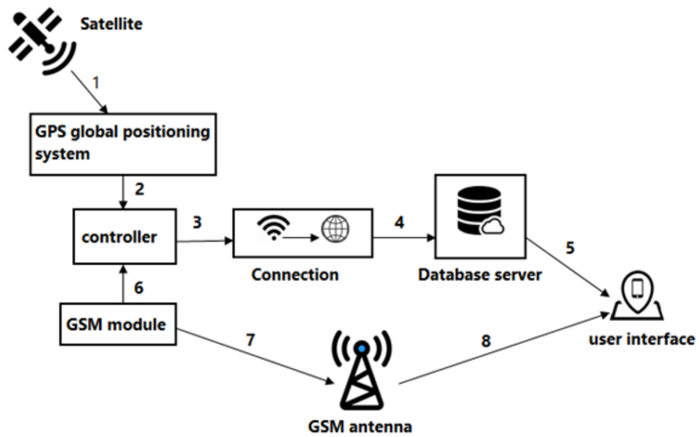

Figure 3.2: Explain the tracking process

Here we translate this scheme into points

1. The GPS sensor receives the signals coming from the satellite and determines the location.
2. Read the location (captured with GPS) by the ESP32 microcontroller.
3. Connect the device to a wifi network.
4. Send the retrieved data to the cloud server for storage.
5. View the patient's location on the map via the app.
6. Connect the controller to the GSM unit in order to send a text message containing the patient's location.
7. Data is transmitted via a GSM network (GSM antenna).
8. View the site as an SMS text message.

3.3.1.2 Architecture of of the data transfer process for heart rate

As for our second structure, which involves explaining the process of sending heart rate data from the device to our Android application through several interconnected components, represented in Figure 3.3, we will then explain the steps one by one.

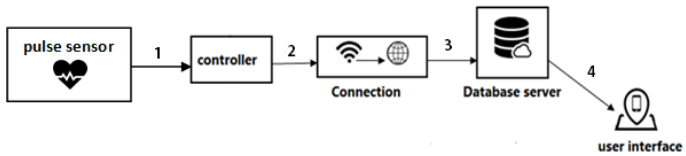

Figure 3.3: Explain the process of calculating the heartbeat

1. Heart rate data acquisition:
   - The heart rate sensor detects the user's heart rate and generates signals.
   - The microcontroller ESP32 receives and processes the heart rate data from the sensor.
2. Data transmission to Firebase:
   - The microcontroller connects to a Wi-Fi network.
   - The microcontroller transmits the processed heart rate data to Firebase, a cloud server, where it is stored.
3. Firebase integration with our Android application:
   - Our Android application establishes a connection to the Firebase database using the Firebase SDK.
   - Our application retrieves the stored heart rate data from Firebase.
4. Heart rate data display:
   - Our application presents the heart rate data within its user interface on the heart rate page.

3.3.2 Electronic architecture

The following diagram represents the electronic circuit of the patient device, which contains an esp32 microcontroller unit in order to control the system and process data and send it via wifi, a GPS unit to track the patient's location, and a GSM unit to send the patient's location via SMS in the absence of an Internet connection and A heart rate sensor to know the patient's heartbeat, a battery 3.7v and a voltage regulator to raise the voltage to 5v to feed the gsm module as we see in Figure 3.4.

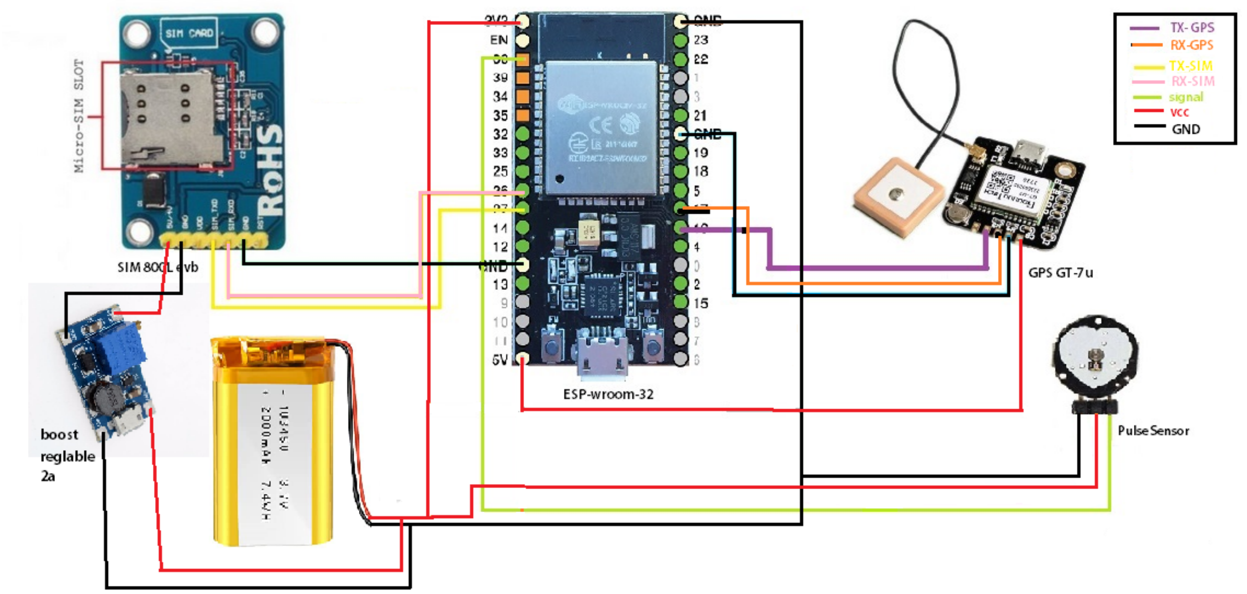

Figure 3.4: The electronic architecture of the device

3.4 System analysis

In this section we will explain the operation of the Alzheimer's patient monitoring system with the Internet of Things, we explained the relationship and the operation of the different components of the system in the form of points:

3.4.1 The goal of the system

The Internet of Things (IoT) and cloud computing are the two main trends in information technology today. The goal of this work is to study these technologies in order to propose and implement a new solution for remote healthcare delivery, specifically for monitoring Alzheimer's patients. This aims to improve their quality of life by enhancing communication and peace of mind. The proposed solution includes supervising medication and doctor appointment management through reminders, tracking their locations, and sending alerts in case they enter an unsafe area. Additionally, it involves monitoring their heart rate to provide health insights to the caregiver and offering a guide for patient care, among other features.

3.4.2 Functional needs

This stage consists of understanding the context of the system. Therefore, for our application, we define a set of business needs that represent the actions that the system must perform:

- Login page: (Authentication) The system (the application) must allow the user (Alzheimer's patient sponsor) to enter their email and password to access the system. This process ensures the security of the system.
- Home page: This is the main page of our application, it differs from other pages in that it presents the user(Alzheimer's patient sponsor) with all the available services clearly and powerfully.
- Patient tracking page: This is the page that will manage the patient tracking functionality through Google Maps. It helps in real-time location determination to ensure the safety and well-being of an Alzheimer's sufferer.
- Reminder list: (medical appointments, medication times...)This page allows the sponsor to view the list of tasks or reminders that must be applied at specific times (for effective time management), and it also contains notifications.
- Care Guide page: This page provides guidance and recommendations for the caregiver on how to help and support someone with Alzheimer's disease.

- User Guide page: This page refers to a document that provides instructions to the user on how to use our application.
- Geo-fence setting page: This page allows the sponsor of an Alzheimer's patient to set geographical boundaries around a specific area, in order to ensure the safety and security of the patient.
- Heart rate page: Is a feature within our application that provides information about the heart rate of a person with Alzheimer's disease. It displays real-time data and is used by caregivers to monitor and track the heart health of their patients.

3.4.3 Non-functional needs

Non-functional needs are essential to improve the quality of our system software. Among these needs:

- Usability: The application must be easy to use and user friendly.
- Performance: The program must above all be effective and optimally meet all needs.

3.5 UML diagrams

To describe how our project works, we chose the standard language UML (Unified Modeling Language) to model our system. It provides standard symbols that simplify reality to understand the system to be developed.

3.5.1 Use case diagram

A use case diagram is a graphical representation used to give an overview of the functional behavior of a system. Describes the interaction between the actor and the system.

To do this, we must first identify the use cases that the users (the Alzheimer's patient sponsor,the the Alzheimer's patient) has done with the system.

3.5.1.1 Application use case diagram

First, we present the diagram of the application part that the figure shows 3.5.

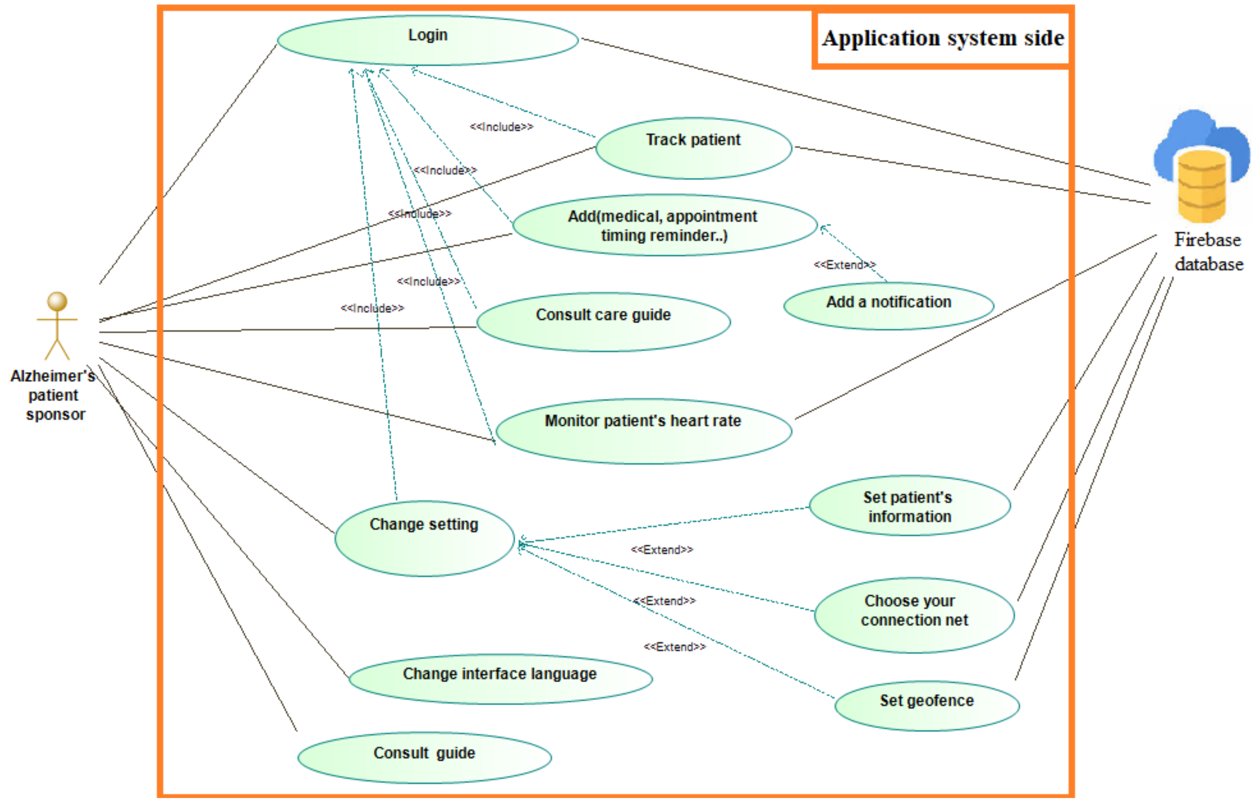

Figure 3.5: Use case diagram (App part)

Now ; We explain the operations that the user can perform with the application.

- Login: Enter your email and password to access the application.
- Track patient:The client can monitor his patient via Google Map, through the information in the Firebase data base(Provided that he has logged in).
- Add a reminder:An Alzheimer's caregiver can add reminders to the list, such as adding an appointment and an alert, but only if they are logged in.
- Change interface language:Our application allows him to change the language to make it easier to understand and use.
- Consult guide:This application provides a user guide (phone use guide)

- Consult care guide:This application also provides a guide with instructions and tips for Alzheimer's patients, but after logging into the homepage.
- Change setting:The Alzheimer's patient's sponsor can add modifications to the patient's information or specify a specific area so that if our patient exceeds it, danger alerts are issued to him, and he is also free to choose the type of device connection to the Internet.
- Monitor patient's heart rate:The caregiver of an Alzheimer's patient can check the heart rate of their patient after logging in.

3.5.1.2 Device use case diagram

As for the relationship of the users (represented by the Alzheimer's patient and his sponsor) to the device, look at the diagram 3.6 below, then we explain to you the interactions that exist.

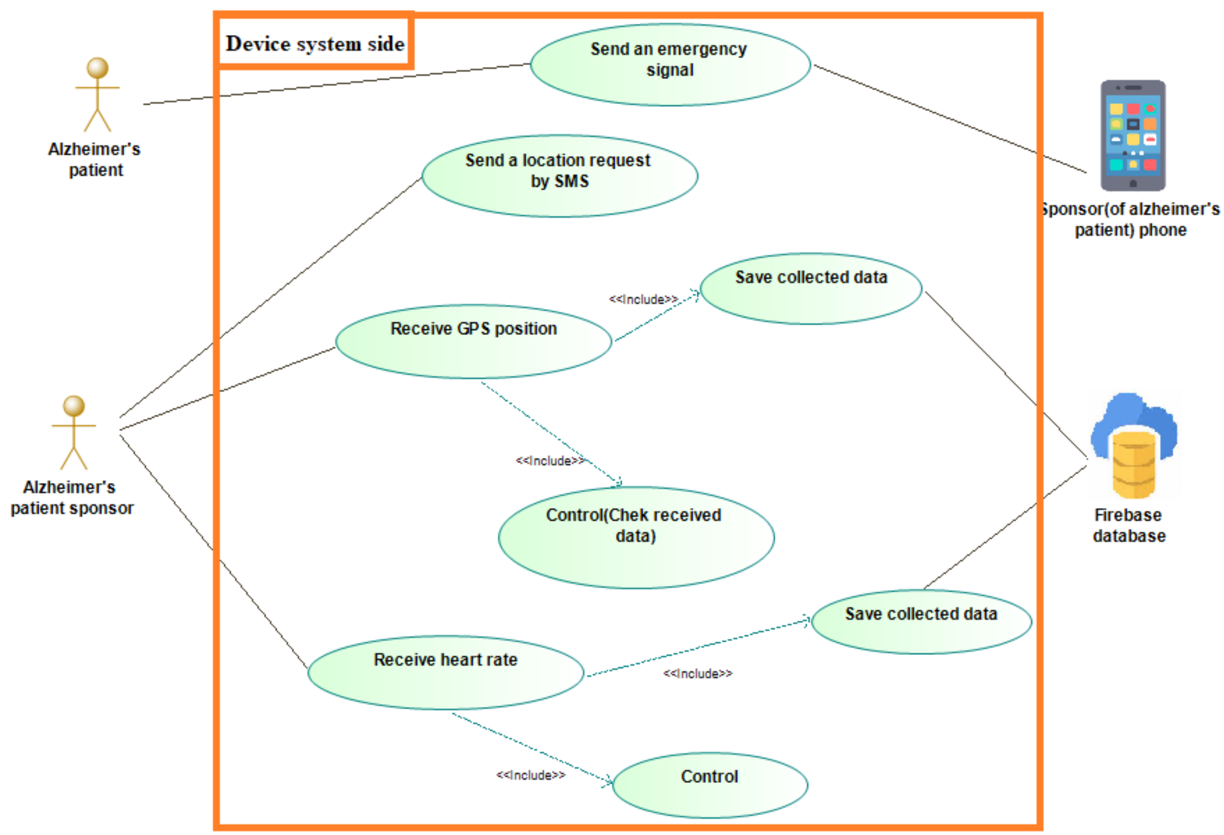

Figure 3.6: Use case diagram (Device part)

- Send an emergency signal: The patient can send a signal to his sponsor to make him feel that he is not well, whether he is inside or outside the house (when he uses this button on the device, he is definitely conscious, i.e. he is not out of memory).
- Send a location request by SMS:In the absence of the Internet, the sponsor of the Alzheimer's patient can find his location by sending a request via SMS. The device sends the location in the form of a link to the SMS.
- Receive heart rate:Our device includes a heart rate calculation process, after which the data is stored in a Firebase database.
- Receive GPS position:The sponsor receives the location from the device, this happens when the GPS receives the information, then it is stored in the Firebase database, and this happens thanks to the controller after it verifies that it has received the data.

3.5.2 Sequence diagram

For a step-by-step view of the use case that shows the sequence of reactions very clearly. We used UML sequence diagrams. It is a diagram that shows the exchange of messages between the system and third parties or between different parts of the system. We will introduce the sequence diagrams in our system (Application specific sequence diagram + Device sequence diagram).

3.5.2.1 Application sequence diagram

Figure 3.7 represents the graph that shows at the beginning that the user (the sponsor of an Alzheimer's patient) before logging in can browse the guide (the application's usage guide or the Alzheimer's care guide) displayed in the form of interaction 1. He can also change the language of the application according to arrow number 2.

Then he enters his e-mail and password, and the system checks the authentication with the Firebase database; if the e-mail or password is incorrect, the system will display a failure message and ask to enter the correct information. Otherwise, it will go to the main page. It is illustrated in the scenario as Operation 3.

Then, after calling and entering the main page, the sponsor chooses what he would like to do.

After pressing the tracking button, note the number 4 arrows, here the application user tracks his patient via Google Map using latitude and longitude data stored in the Firebase database.

But if he chooses to add a reminder (such as sending an alert at 9 am to go to a medical examination or a special sport for the patient with his coach), then he must choose the reminder button. Number 5 shows a sequence of how to add it.

And number 6 in this diagram shows that the user is able to change his patient's information, or choose the type of device connection to the Internet (ADSL / 2G), or specify / change a geographical area, and if his patient exceeds it, the device sends an alarm.

Arrow number 7 represents how the process of reading heartbeats from the database is performed.

According to the arrow indicated by number 8, the user can browse the Alzheimer's patient care guide.

Lastly,the last arrow numbered with 9.1 represents the final step when finishing the use of the application and clicking on the logout button. At this point, the user's activity ends because they have exited the application.

3.5.2.2 Device sequence diagram

Figure 3.8 represents the diagram that shows how the device works. At first, the device connects to the Internet as represented by interaction 1. As we can see in interaction 2, the device captures the coordinates of the device by GPS every 5 minutes and saves them in firebase.

Interaction 3 represents the process of examining the incoming message from the caregiver in case he sends an sms message to obtain the location of the patient, in this process the device checks the message if it contains the word "tracking" and sends the coordinates to the sponsor to obtain his phone number from the information registered in firebase.

For Figure 3.9, interaction 4 represents the process of examining the patient's location (inside or outside the geo-fence) in the absence of an internet connection in the device. In this process, if the patient leaves the specified geo-fence, it sends an SMS message to the sponsor containing the patient's location and an alert that he outside the safe zone.

The patient can send an emergency single when he feels lost or insecure, as represented by interaction number 5 The last interaction represents the process of sending the patient's heart-beat on demand, interaction 6.

3.5.3 Class diagram

The following figure 3.10 shows the class diagram of our system structure, which is a graphical representation of our elements connected by relationships.

1. The sponsor(caregiver) can browse the application interface.
2. The application interface includes a login.
3. You can validate his heart rate, track, add reminders, and modify entries after logging in.
4. The microcontroller controls the sensor contract after collecting the information.
5. All information is stored in the Firebase database, and this information can be sensor data controlling by the microcontroller, or patient data, identity verification data... They are inputs and outputs to this database.

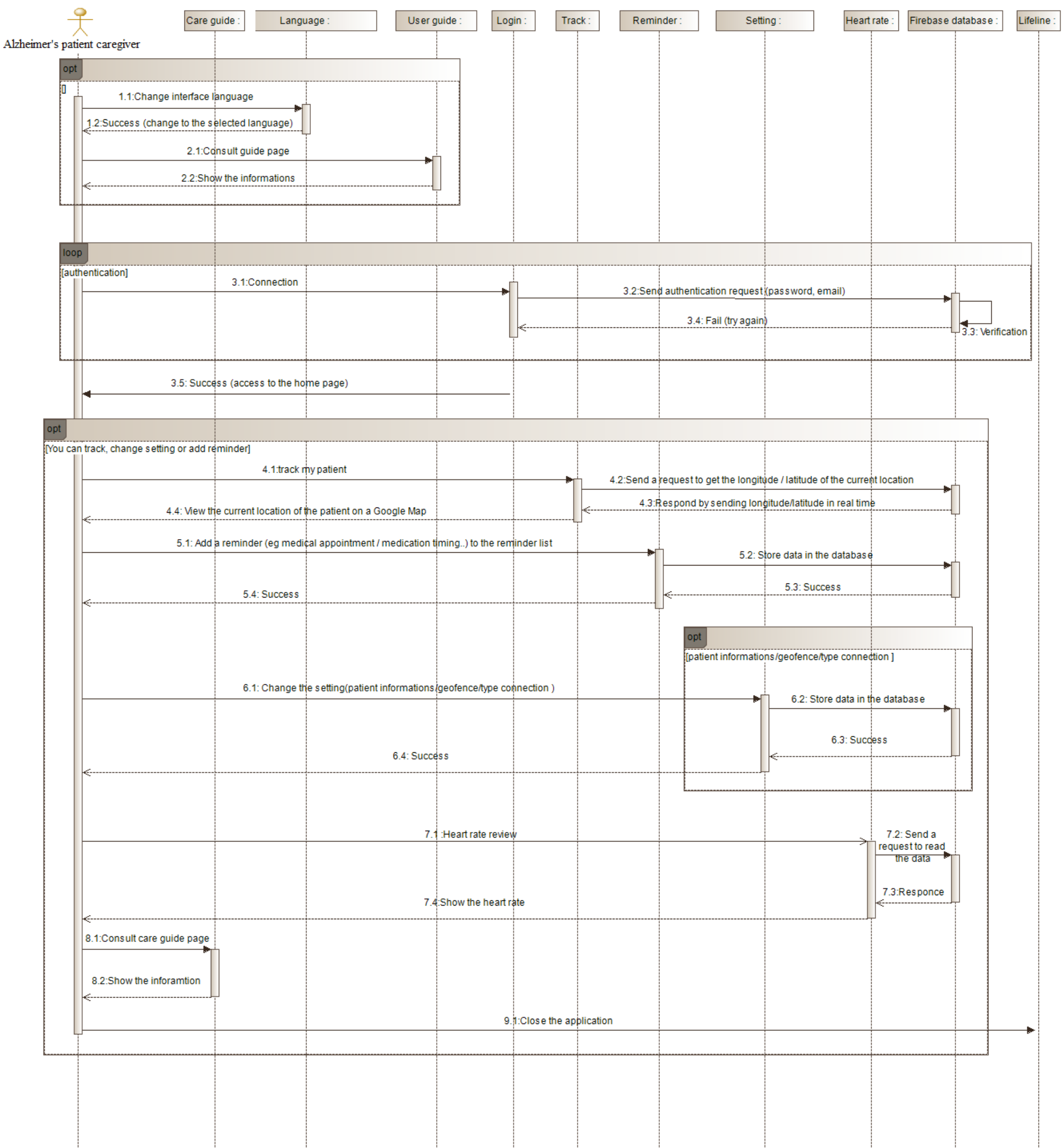

Figure 3.7: Sequence diagram (Application part)

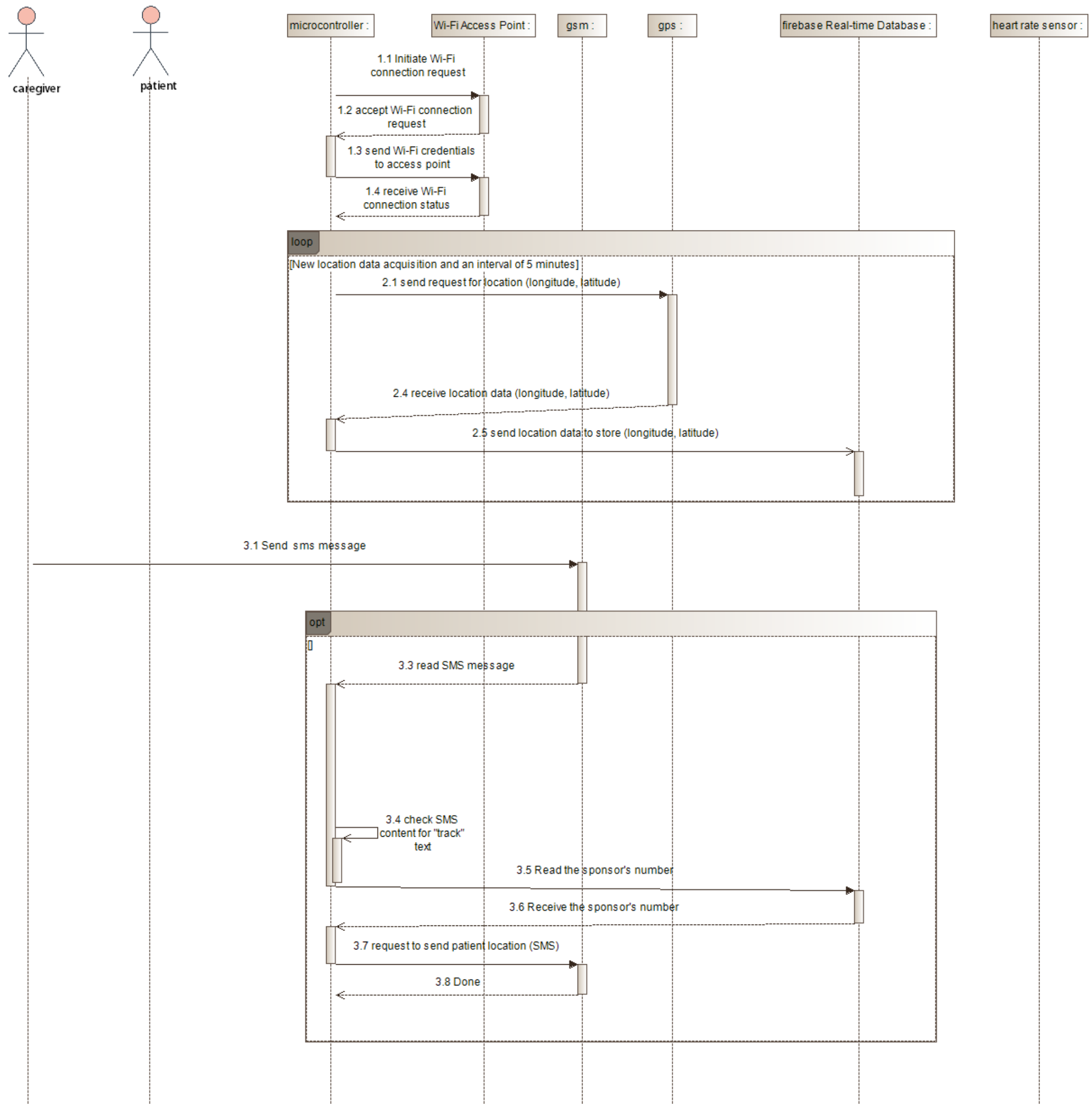

Figure 3.8: Sequence diagram (device part1)

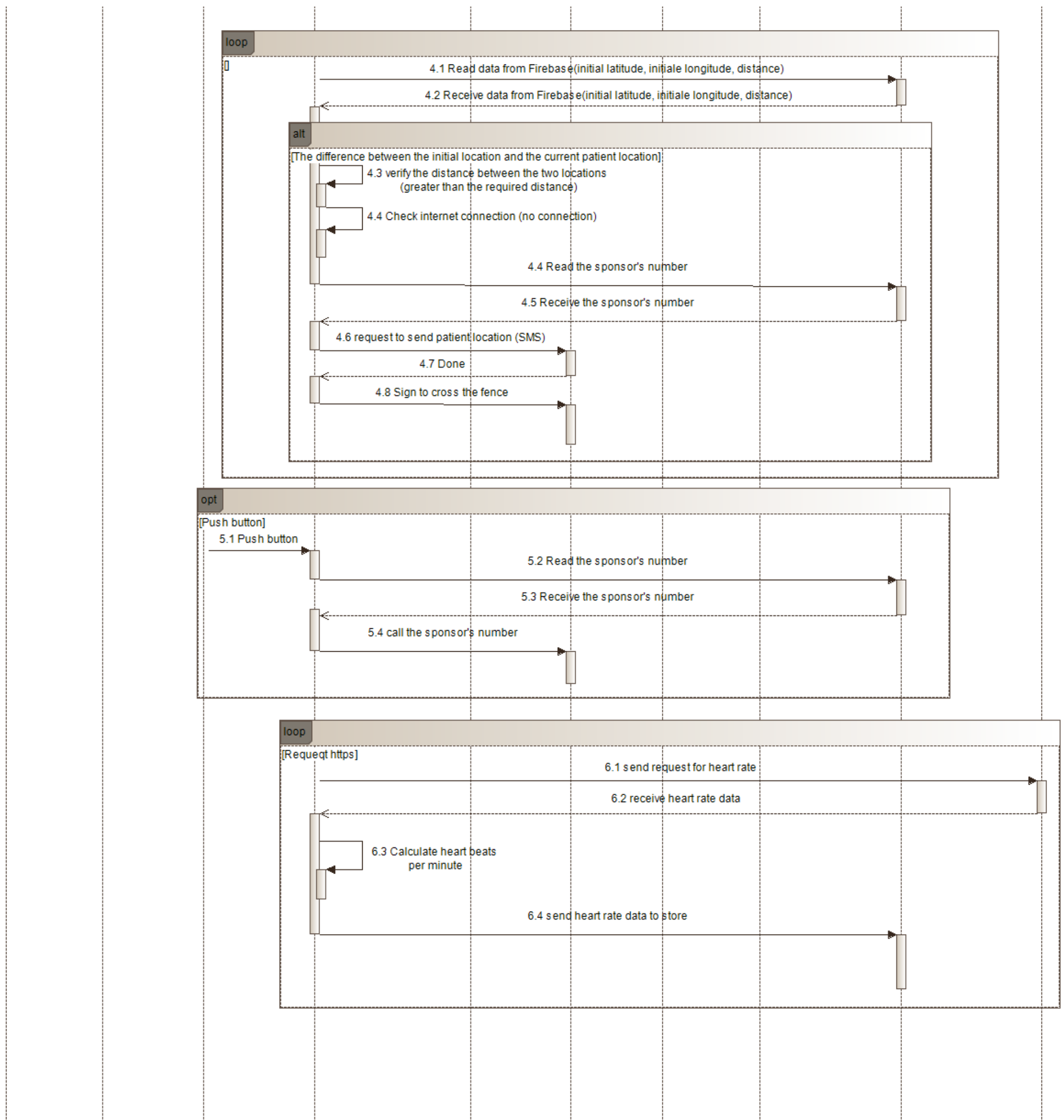

Figure 3.9: Sequence diagram (device part2)

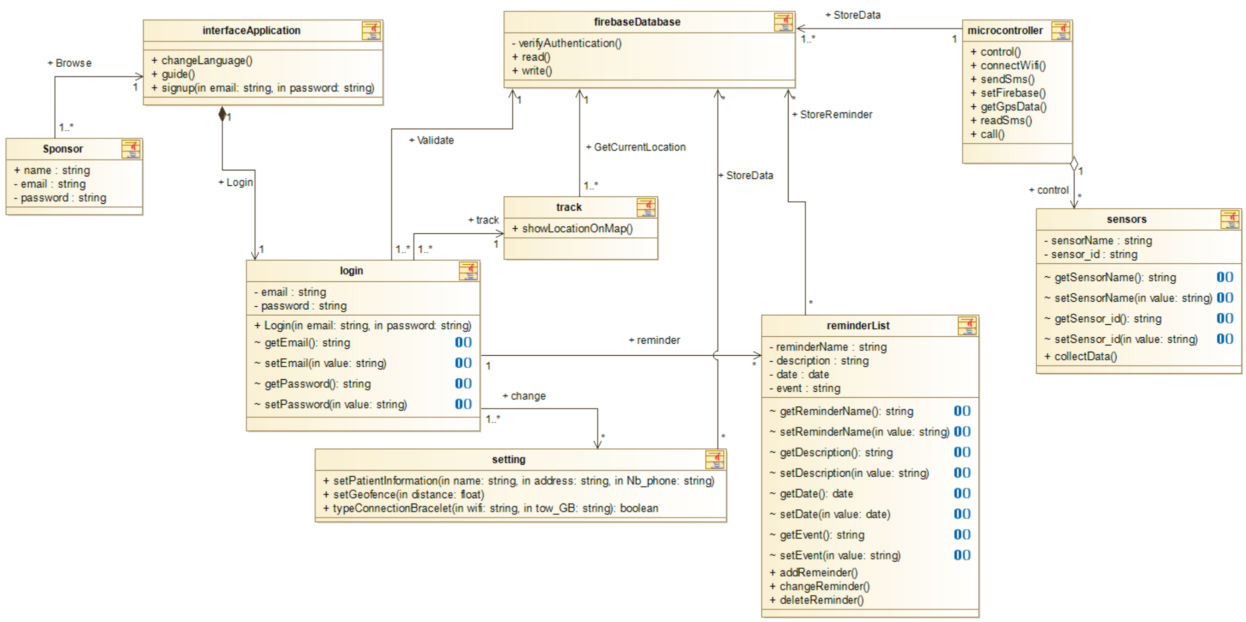

Figure 3.10: Class diagram

Chapter 4

Implementation

4.1 Introduction

In this chapter we will describe the steps we followed to develop and realize our IoT solution.We will present brief definitions regarding the programming languages used to develop our system, mentioning the electronic equipment used to create this effective device to help Alzheimer's patients.

We will explain all this in detail, and cite images of the solution we proposed ,and now it became a reality, which is our prototype and care application for Alzheimer's patients (device and app).

4.2 Programming language

There are many programming languages. In our project, we used Java and C languages to program the application and the device (respectively).

4.2.1 Java

The Java programming language was released in 1995 by James Gosling[7].It is a class-based, object-oriented programming language that is designed to have as few implementation dependencies as possible. It is a general-purpose programming language intended to let application developers write once, run anywhere (WORA), meaning that compiled Java code can run on all platforms that support Java without the need for recompilation.Java applications are typically compiled to bytecode that can run on any Java virtual machine (JVM) regardless of the underlying computer architecture. We used the Java language to program our mobile application.

Figure 4.1: Java

4.2.2 C

The C programming language was designed in the early 1970s, it's not a "very high level"language, it's not a big language, and it's not specialized in any particular area of application[40]. C has been used in a wide variety of programs, including the UNIX operating system, and the language is expressive and efficient enough that it will replace assembly language programming on UNIX. C compilers run on a variety of devices. We used the C language to program the esp32 microcontroller for the device.

Figure 4.2: C programming

4.3 Development tools and frameworks

In this section, we present the tools and frameworks used in implementing our project.

4.3.1 Firebase database

Firebase is a development platform launched in April 2012 and acquired by Google in 2014 as a back-end developer solution.

The combination of features in Firebase is one of the cloud databases. It works in both web and mobile applications. Firebase is divided into 3 modules: Development, Profit, and Growth. Depending on the characteristics of the application, the customer can deploy one of these three pillars or integrate all Firebase functions for basic data synchronization[47]. It is a highly secure system.

4.3.2 Arduino ide

Arduino IDE is an open source software that is mainly used for writing and compiling code in the Arduino Module[17].We will define it in points:

1. It is an official Arduino software, making code compilation too easy that even a common person with no prior technical knowledge can get their feet wet with the learning process.

2. It is easily available for operating systems like MAC, Windows, Linux and runs on the Java Platform that comes with inbuilt functions and commands that play a vital role for debugging, editing and compiling the code in the environment.

3. A range of Arduino modules available including Arduino Uno, Arduino Mega, Arduino Leonardo, Arduino Micro and many more.

4. Each of them contains a microcontroller on the board that is actually programmed and accepts the information in the form of code.

5. The main code, also known as a sketch, created on the IDE platform will ultimately generate a Hex File which is then transferred and uploaded in the controller on the board.

6. The IDE environment mainly contains two basic parts: Editor and Compiler where former is used for writing the required code and later is used for compiling and uploading the code into the given Arduino Module.

7. This environment supports both C and C++ languages.

4.3.3 Android studio

Android studio is anew IDE(Integrated Development Environment) made available for free Google to Android Developers and it is flexible build system [15].It include many tools to develop the application. such as(launch google Browser, connect to internet, send messages ,view the basic information of the device(memory space, and security)).

Plus it offers these tools:

1. Build variants and multiple apk file generation.
2. Code templates to help the developer to build common application features.
3. Rich layout editor with support for drag and drop theme editing.
4. lint tools to catch performance, usability, version compatibility, and other problems.
5. ProGuard and app-signing capabilities.
6. Built-in support for Google Cloud Platform, making it easy to integrate Google Cloud Messaging and App Engine.

4.4 The electronic equipment.

In this section, we will describe the electronic devices used in our project.

4.4.1 ESP-WROOM-32

Or ESP32 model (also called ESP32 microcontroller),it "is a powerful, generic Wi-Fi + Bluetooth + Bluetooth LE MCU module that targets a wide variety of applications, ranging from low-power sensor networks to the most demanding tasks, such as voice encoding, music streaming and MP3 decoding"[38].

Figure 4.3: Model ESP32[38]

4.4.2 SIM800l EVB module

SIM800L is a quad-band GSM/GPRS module[50], operating on several frequencies including GSM850MHz, EGSM900MHz.

The operating voltage range of the chip is from 3.7 to 5 volts. In order to work, it requires a GSM cellular sim from any mobile service provider. The connection supports a link down/uplink transmission speed of 85.6kbps, which is more than enough for the required data bandwidth[21]. This data packet is light, containing only a few bytes per packet.

Figure 4.4: SIM800l EVB module

4.4.3 GT-U7 GPS modules(Goouuu Tech GT-u7)

"The selected GPS sensor is by Goouuu Tech Company, the model is GT-U7. The sensor comes with several protocols which is UART, USB to interface it with USB supported MCU and it is also compatible with Serial Peripheral Interface (SPI). The sensor built with powerful power management, with echo Mode to save power when location information is not changed. The accuracy is very high, supported with A-GPS and Assist Now Autonomous feature"[6].

Figure 4.5: GT-U7 GPS SENSOR[6]

4.4.4 Pulse sensor

"The pulse sensor module measures heart rate using light reflection. When the finger is placed on the device, light reflection changes based on the blood volume in capillary vessels during a heartbeat. This variation is detected and output as a pulse. The pulse can be conditioned and programmed to display the heartbeat count. The sensor has a front side with a heart logo, LED, and light sensor, while the back side houses the other components"[26].

Figure 4.6: Pulse sensor[26]

4.4.5 3.7 V Li-Po Rechargeable Battery, 2000mAh

4.5 The main algorithms of the system

We have compiled the core and standout pseudo algorithms that we have developed in our project, and we are pleased to present them to you now.

4.5.1 Pseudo algorithms on the application side

On the application side, there are 4 main texts that we will explain in the following pseudo algorithms, which are executed by the mainActivity.

4.5.1.1 Pseudo algorithm for tracking

As mentioned before, in the application section, we have the tracking feature. The following pseudo algorithm is a script that reads the current location information from the database Firebase and displays it on a Google map.

Algorithm 1 Track

inputs: urlFirebase,longitude , latitude | Outputs: location

Begin

firebaseDatabase($urlFirebase$)\\$initialisation + connxion$

if firebaseDatabase is Connected **then**

  repeat(*longitude is Changed* ***or*** *latitude is Changed*) is **False**

    { longitude ← get data from firebase

    latitude ← get data from firebase

    showLocationInMap($longitude, latitude$){

      return location }

    }

else write(" Failed to connect to the Firebase database") \\$showMessage$

End

4.5.1.2 Pseudo algorithm for geofencing

The “geofenceActivity” contains the functionality to set a distance (radius) chosen by the caregiver, so that if the patient exceeds this distance, the application issues a notification indicating that they have exceeded the safe zone.

Algorithm 2 Geofence

inputs: distance,longitude, latitude,urlFirebase | Outputs: distance2

$\backslash\backslash distance = DistanceBetweenLongitude/latitudeInitialAndBoundary$

$\backslash\backslash distance2 = DistanceBetweenDeviceAndLongitude/latitudeInitial$

Begin

firebaseDatabase($urlFirebase$)$\backslash\backslash initialisation + connxion$

if firebaseDatabase is Connected **then**

  repeat(*longitude is Changed* ***or*** *latitude is Changed*) is **False**

    { longitude ← get The initial longitude point from firebase

    latitude ← get The initial latitude point from firebase

    distance ← get The distance point from firebase

    distance2 ← calculateDistance($longitude, latitude, distance$)

    if distance2>distance **then**

    sendAlert() }

else write(" Failed to connect to the Firebase database") $\backslash\backslash showMessage$

End

4.5.1.3 Pseudo algorithm for the reminder

The following pseudo algorithm represents the script that is executed in our “reminderActivity” and its role is to set a specific event date related to an Alzheimer’s patient.

Algorithm 3 Reminder

inputs: task,time,date | Outputs: notification

Begin

setEvent($task$)

setDate($date$)

setDate($time$)

addinList($task, time, date$) $\backslash\backslash storageThisInformationInListAndInFirebaseDatabase$

if date and time is now **then**

sendAlert()

End

4.5.1.4 Pseudo algorithm for changing settings

The following pseudo algorithm represents how to change the settings for patient information (there are three options available to change their settings: geofence, device connectivity type, and patient information). However, for the purpose of understanding the process, we have only included how to change patient information as an example.

Algorithm 4 Change setting"patient's information"

inputs: address,surname,name,age,phoneNum | Outputs: notification

Begin

setNewInformations($address, surname, name, age, phoneNum$)

saveInFirebase($address, surname, name, age, phoneNum$)

showNewInformations()

End

4.5.2 Pseudocode algorithm on the device side

The algorithm of a device plays a crucial role in its operation and functionality. It serves as a set of instructions and logical steps that enable the device to perform specific tasks or processes efficiently.

Therefore, we will provide you with some pseudo algorithms that illustrate how the device processes data.

4.5.2.1 Pseudo algorithm for geofencing

This pseudo-algorithm provides a simplified overview of how to adjust device geolocation settings based on distance calculations..

Algorithm 5 Geofence

Begin

distance2← calculateDestance()

$\backslash\backslash distance2 = DistanceBetweenDeviceAndLongitude/latitudeInitial$

if distance2>distance **then** {

$\backslash\backslash distance = DistanceBetweenLongitude/latitudeInitialAndBoundary$

    sendLocation()

    sendAlert() }

else sendMessage("Return to the safe region") $\backslash\backslash showMessage$

End

4.5.2.2 Pseudo algorithm for GPS

This pseudo-algorithm exposes the process of communicating with a GPS device, reading and processing GPS data with a microcontroller, and storing the data in a Firebase database.

Algorithm 6 GPS

Begin

connectGPS()

while GPS data is available **do** {

    readGPSData() $\backslash\backslash byMicrocontroller$

    treatmentGPSData()

    storageFirebase()

    sleep(50000) }

End

The pseudo-algorithm continues to loop, repeatedly executing the steps mentioned above as long as GPS data remains available. This algorithm serves as a theoretical representation of how GPS data can be processed and stored using a microcontroller and a Firebase database.

4.5.2.3 Pseudo algorithm for tracking by SMS

The pseudo-algorithm specifies the required steps for processing incoming SMS messages providing the caregiver with the current location upon request, and periodically checking for the availability of GSM data. Although this algorithm is fictional, it provides an insightful overview of the general flow of an SMS-based location sharing system.

Algorithm 7 SMS

```
Begin
sendCurrentLocation{
    longitude← get longitude from GPS
    latitude← get latitude from GPS
    definedNumCaregiver()
    definedSMSMessage() \\longitude + latitude + link
    sendMessage()}
\\Receive
while GSM data is available do{
    msg← readSMS()
  if msg is equal "track"  then
        sendCurrentLocation()}
End
```

4.5.2.4 Pseudo algorithm for emergency signal

The following pseudo-algorithm provides an implementation of the process of generating an emergency signal on button click and notifying the designated caregivers. It is important to note that this algorithm serves as a conceptual illustration of the process as it provides insights into the emergency signaling system based on button click events.

Algorithm 8 Emergency signal

```
Begin
if button is on click then{
        definedNumberCaregiver()
        sendSignal()}
  End
```

4.6 Mobile web application

The SaaS interface is a cloud-hosted web application that allows us to monitor and manage the patient's movements and information, providing the caregiver with an easy-to-use method for accessing the application's features and data online.

4.6.1 Sign up Page

In order for the caregiver to monitor and track the Alzheimer's patient, they need to create an account on our application through this page, which requires entering a set of personal information (email and password) displayed in the images 4.7 , 4.8 , 4.9 , 4.10 , 4.11 , 4.12 below. The image also illustrates the language change feature on this page, along with a button for the user guide.

4.6.2 Login page

This page allows the user to log in to their account on our ALZ care application,look at the picture4.13.

4.6.3 Home Page

This page contains a menu that allows the caregiver to navigate to the different pages they need, which will be described below 4.14.

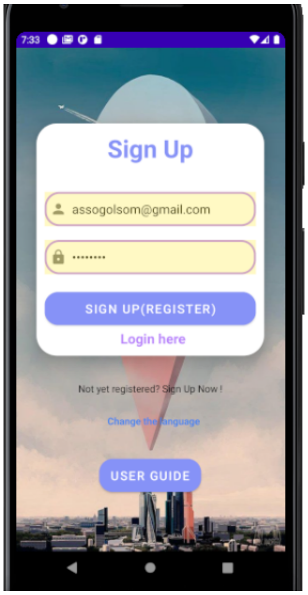

Figure 4.7: Sign up

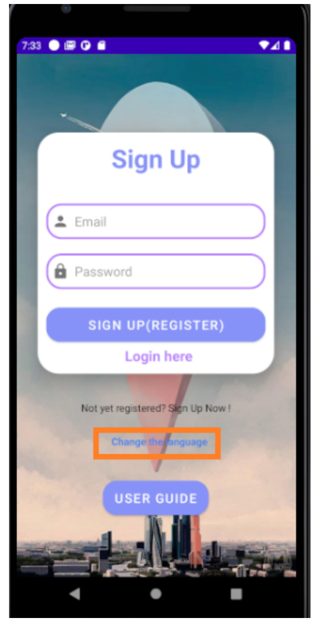

Figure 4.8: Change language

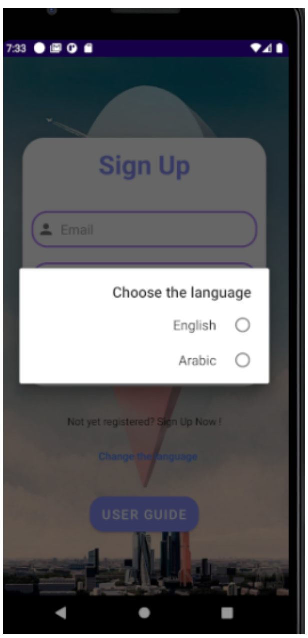

Figure 4.9: language

Figure 4.10: Sign up page in arabic

4.6.4 Caregiver Guide Page

This page is one of the most important pages that caregivers need, as it allows them to access all the tips and guidelines related to Alzheimer's patients for providing specialized care and better understanding without the need for searching. As shown in the picture 4.15.

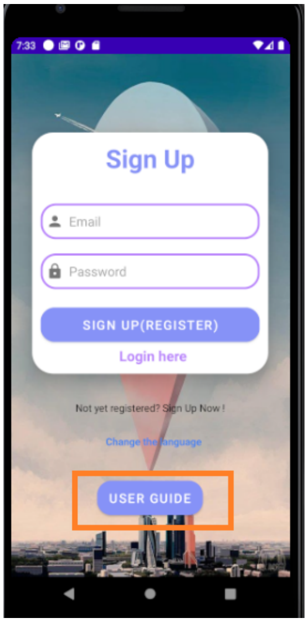

Figure 4.11: Button user guide

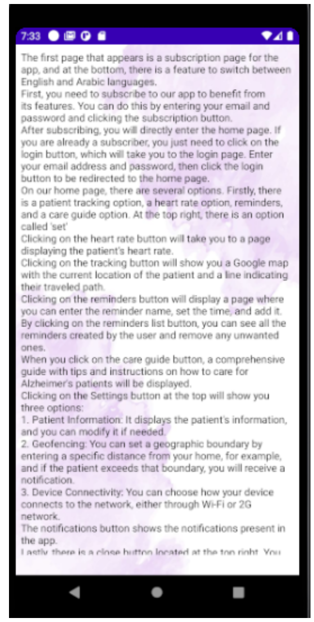

Figure 4.12: User guide page

,

4.6.5 Tracking Page

This page allows the caregiver to view the location of the patient and track them using Google Maps, facilitated by the device worn by the Alzheimer's patient(look at the figure4.16 and 4.17) .

4.6.6 Heart Rate Page

This page contains the display of the patient's heart rate through our device worn by the Alzheimer's patient(figure4.19).

4.6.7 Reminders Page

This page allows the caregiver to set specific reminders for the patient, such as medication timings, exercise schedules, medical appointments, and other reminders needed for Alzheimer's patients. Once the reminder is added, it will appear as an alert and will be directly added to the list of notifications.As described in 4.20,4.21.

4.6.8 Setting

This page consists of a menu of pages (look at the picture 4.22)that allow the caregiver to review certain data, including:

1. Changing information about the patient(look at 4.23).
2. Selecting the device's communication type(look at the figure 4.24).
3. Setting up a geofence (defining a specific area), note the image 4.18 .

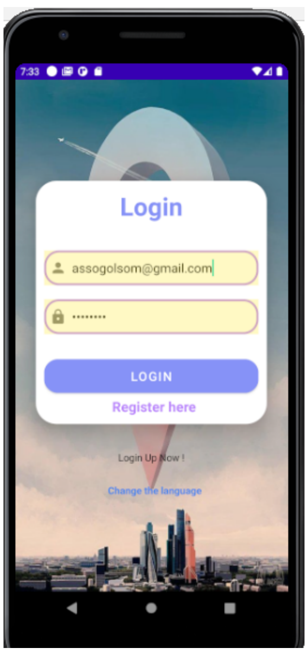

Figure 4.13: Login page

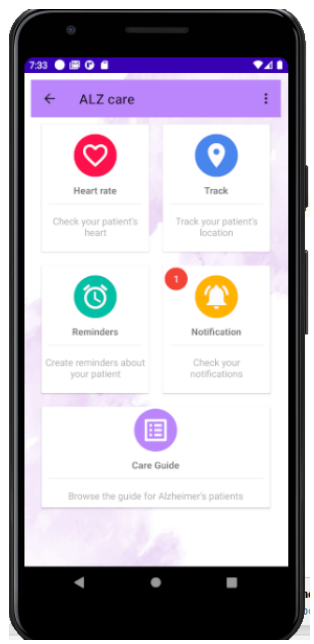

Figure 4.14: Home page

4.7 Wearable device

We present to you our advanced wearable device, a technological marvel designed to empower and protect Alzheimer's patients by integrating advanced monitoring technologies and capabilities. We have placed a greater emphasis on efficiency, and the design is still evolving for the better. Here are the following pictures 4.25 ,4.26.

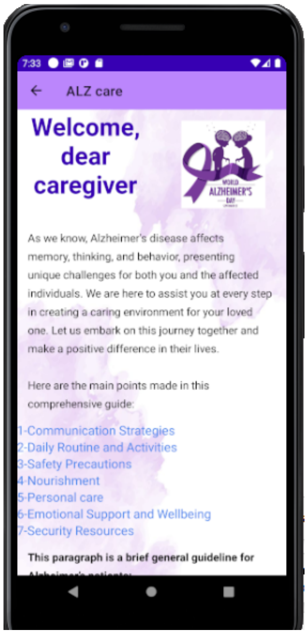

Figure 4.15: Caregiver Guide page

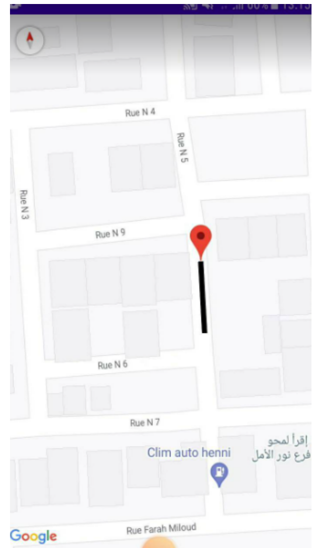

Figure 4.16: Tracking page

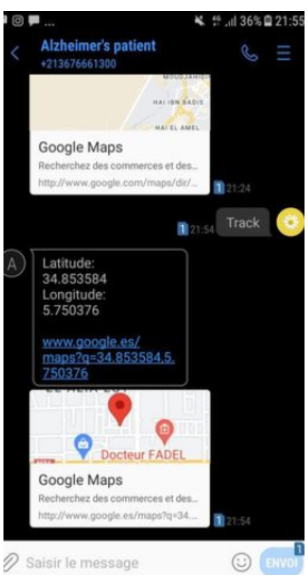

Figure 4.17: Tarck by SMS

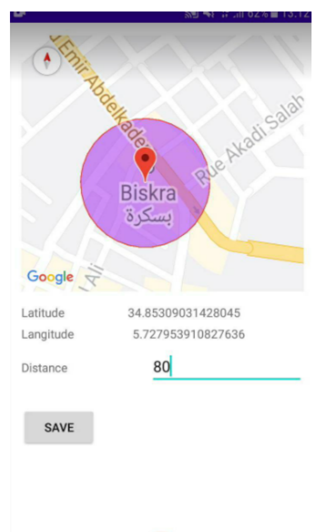

Figure 4.18: Geofence page

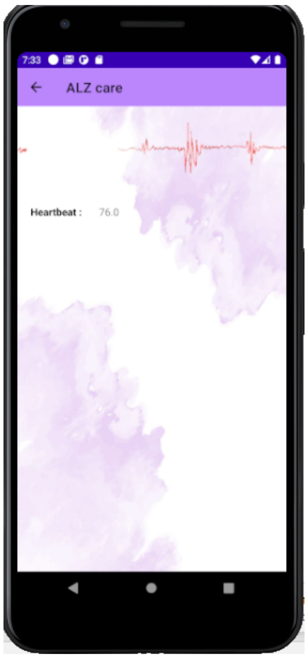

Figure 4.19: Heart Rate page

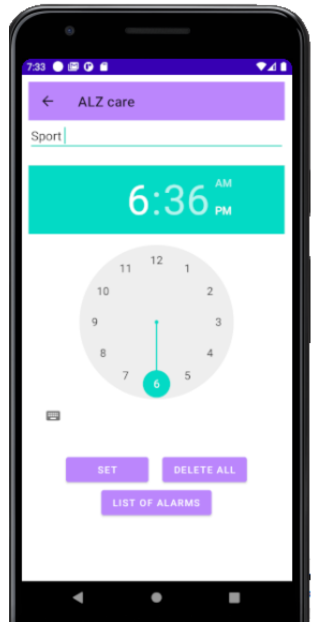

Figure 4.20: Reminders page

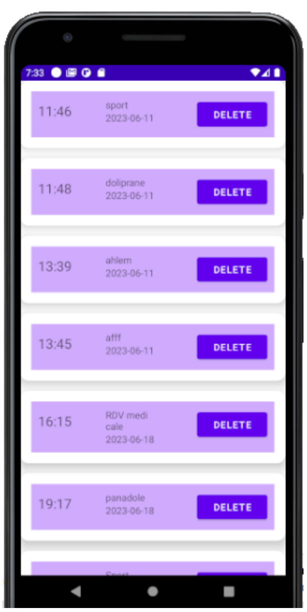

Figure 4.21: List reminders page

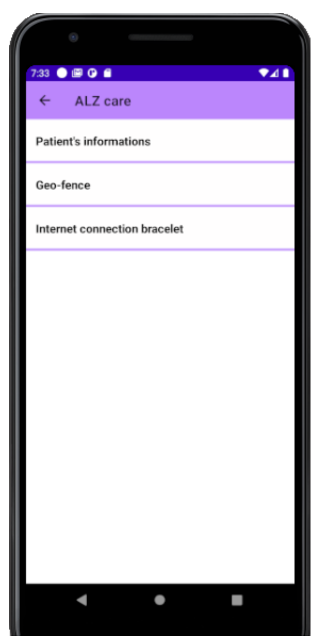

Figure 4.22: Setting

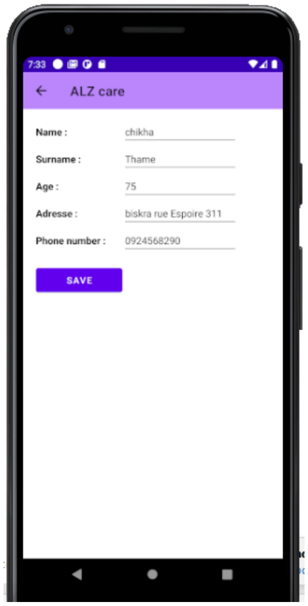

Figure 4.23: Information's patient

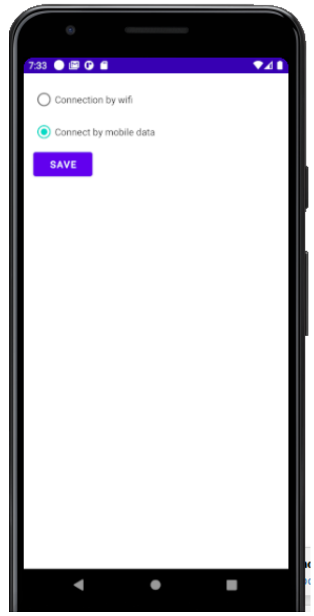

Figure 4.24: Device connection type

Figure 4.25: A picture of our wearable device

Figure 4.26: A picture of our wearable device

4.8 Conclusion

In this chapter, we have discussed the tools, libraries, and frameworks we used in our study. We have also discussed the important and prominent algorithms we developed and implemented a significant portion of our system. We have presented the results in the form of illustrative images of the processes we have embodied in our application and prototype.

Chapter 5

Conclusion and Perspectives

5.1 Conclusion

Taking care of the elderly can be a challenging responsibility, especially when they are diagnosed with Alzheimer's disease. In this project, we benefited from the concept of the Internet of Things as a solution for providing care to Alzheimer's patients by connecting caregivers with their loved ones. The solution we presented consists of two main parts. The first part involves the Alzheimer's patient wearing a wearable device, while the second part is downloading an Android application on the caregiver's mobile phone, which should be connected to the patient's device to access and store their heart rate and location data. We integrated two technologies, GPS and GSM, to determine the geographical location. Some of the challenges we encountered in our work were device incompatibility and electrical difficulties.

To begin with, we started with a presentation about Alzheimer's disease and provided a general description of it. Then, we discussed the Internet of Things (definition, structures, functions), along with a presentation on geographical location tracking. We concluded the chapter with a brief overview of cloud computing.

The third chapter was dedicated to system design and analysis, supported by diagrams and structures to enhance understanding and clarify how the system works.

In the fourth chapter, we discussed the practical part, starting with the programming languages and tools we used, and then the hardware section, where we mentioned the components used in our project. We also touched on some notable algorithms. We revealed the results obtained from geographical location tracking and heart rate monitoring, along with features such as task scheduling reminders for activities like bathing, exercises, patient medications, and medical appointments. Additionally, there is a section where caregivers can obtain information about Alzheimer's disease and how to care for their patients.

5.2 Perspectives

However, several aspects of this study might be improved, which we see as promising for our work.

-Integrating artificial intelligence to predict the location of the affected individual.

-Developing and customizing the device for multiple groups, such as patients with autism and children

-Community awareness.

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