WaveSafe: Design of an IoT System for Monitoring of Elderly People

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***Abstract*— This paper introduces WaveSafe, an IoT-based system designed to enhance elderly care through non-intrusive monitoring. Using radar technology, the system detects motion and identifies anomalies, such as falls, without relying on cameras or wearables, ensuring privacy. Data is processed locally to provide real-time alerts while also being transmitted securely to the cloud for long-term analysis. The system is cost-effective, scalable, and tailored to meet the growing need for reliable and innovative elderly care solutions. Through a detailed market study, WaveSafe is shown to address gaps in existing solutions by combining privacy-focused design and predictive analytics.**

Keywords*— *IoT, elderly care, edge computing, anomaly detection, sensors, health monitoring, predictive analysis.

I. Introduction

The increasing global aging population presents significant challenges for caregivers, healthcare providers, and families. In many cases, constant human supervision of elderly individuals is not feasible, especially in situations where they live alone or have limited access to in-person care. To address this issue, IoT-based monitoring systems offer a promising solution, providing continuous surveillance while enabling remote alerts in the event of unusual activity.

This paper proposes an IoT system that uses a radio wave radar to detect movement in the environment of elderly individuals. The collected data is processed locally to reduce latency, ensure real-time responses, and support privacy through non-visual monitoring. The system is designed to monitor daily activity patterns, detect anomalies through non-intrusive monitoring, and notify caregivers or emergency services when needed.

In the following sections, we will outline the technical specifications of the system, conduct a preliminary market study on existing solutions, and discuss the differentiating aspects of our proposal, including its capabilities, cost-effectiveness, and scalability. Additionally, we will address the usability of the system from the perspective of its target users and provide a roadmap for future development and deployment.

II. System Usability: User Storyboard

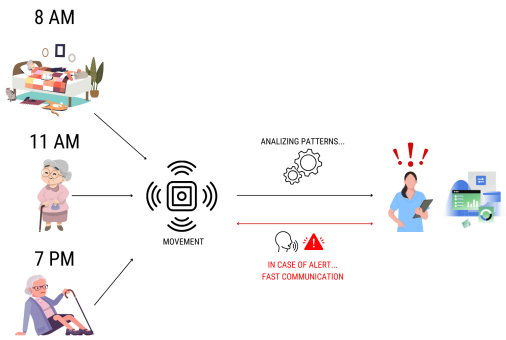

Fig 1: user storyboard

Our system is designed to monitor elderly individuals using radar-based motion detection, providing continuous and non-intrusive supervision to ensure their safety. Throughout the day, the system detects and analyzes daily activities, creating a baseline of normal patterns. For instance, it recognizes regular movements, like getting out of bed in the morning or walking around during the day. If an anomaly occurs, such as a potential fall or prolonged inactivity, the system triggers an alert, notifying caregivers in real-time. Additionally, the system provides contextual data for caregivers to help them respond promptly and effectively, ensuring privacy and peace of mind by avoiding intrusive visuals. This allows caregivers to monitor loved ones remotely, offering peace of mind and ensuring timely interventions in case of emergencies.

III. Preliminary Market Research

To validate the originality of the proposed IoT-based elderly monitoring system, a preliminary market study was conducted to analyze existing solutions. The study examined cost, privacy features, functionality, and performance, focusing on identifying gaps where our solution's non-intrusive, radar-based monitoring approach provides an advantage.

A. *CarePredict* [1]

- $449 initial hardware setup, $69/month subscription.
- Uses wearable sensors to monitor daily activities like walking, eating, and sleeping, with machine learning to detect deviations.
- Relies heavily on wearables, leading to possible compliance issues due to user reluctance or forgetfulness.

B. *Curo* [2]

- Starts at $60/month, additional hardware fees apply.
- Utilizes non-invasive sensors placed around the home to monitor activities such as door usage and appliance interaction. Caregivers receive real-time updates through a dedicated app.
- Provides robust data on daily routines but lacks advanced predictive analytics for preemptive emergency detection.

C. *SafeBeing* [3]

- $30-$50/month, variable hardware costs.
- Wearables monitor hydration, sleep, and falls with AI-driven real-time alerts.
- Continuous wearable usage required, presenting potential compliance challenges similar to CarePredict.

D. *Walabot HOME (now named Vayyar)* [4]

- $249 one-time fee.
- Wall-mounted radar technology detects falls and automatically notifies emergency contacts.
- Limited to fall detection, without broader health, faster communication or activity monitoring capabilities.

E. *Alexa Together (Discontinued)* [5]

- Previously $19.99/month.
- Provided remote caregiver monitoring, alerting when daily interactions with Alexa devices or movements were missed.
- User insights from Reddit highlighted the demand for a simple, non-invasive monitoring tool. Our system fills this void with continuous, non-intrusive monitoring.

F. *Protección Senior - Securitas Direct* [6]

- €24/month for one user, €34/month for two users.
- A telecare service with a smartwatch that offers fall detection, activity tracking, and environmental monitoring. It connects to a 24/7 emergency center, responding within 30 seconds. A mobile app provides real-time updates to family members.
- The system requires wearing the device, which may cause compliance issues.

G. McRoberts [7]

- Price not available.
- A Dutch telecare system that uses wearable sensors to monitor elderly individuals' movement and falls. It provides real-time data on activity levels and can alert caregivers to unusual patterns. The system is used in both home care and professional settings, offering detailed analytics to improve elderly care.
- It relies on wearable devices, which may lead to compliance challenges for some users.

The analysis supports the differentiation of our system, which emphasizes non-intrusive, radar-based monitoring. By removing the need for wearables or camera-based monitoring, our approach enhances privacy and usability, addressing limitations in existing solutions.

IV. System Proposal

Our IoT system differentiates itself by offering non-intrusive monitoring through a radar-based approach, eliminating the need for wearables and cameras. The system utilizes real-time edge computing for immediate anomaly detection, minimizing false alarms and ensuring privacy.

1. *Multisensor Monitoring Devices*

Unlike Alexa Together, which was voice-enabled only, our system incorporates radar technology for detecting movement and audio monitoring.

We propose using a radar sensor and microphone as the primary sensing devices, which will be strategically placed indoors to monitor elderly individuals.

These devices are designed for indoor monitoring in nursing home environments, with future potential for outdoor adaptations.

2. *Privacy and Data Security*

Ensuring privacy is critical. All radar and audio data will be processed locally (via edge computing) to minimize cloud data exposure.

Data transmitted to the cloud will be encrypted and anonymized, with strict access controls to protect the privacy of users.

V. Functional Specifications

This section outlines the functional requirements for each component, spanning the device, edge, and cloud layers.

1. *Radar sensor*

The radar sensor, utilizing mmWave technology, detects movement within indoor spaces with enough precision to distinguish between different types of human motion, such as sitting or falling. It transmits this movement data to the processing device for real-time monitoring and processing. The radar sensor requires a steady DC power supply (3.3V or 5V). Since power outlets provide AC voltage, an AC-DC converter is necessary.

2. *Communication System (Microphone and Speaker)*

The microphone and speaker function as a communication system, similar to a phone, enabling direct audio communication between the patient and caregivers. Both devices remain inactive by default, activating only during an incoming call from caregivers or when the patient initiates contact. The patient can initiate contact by screaming, saying a keyword, or pressing a button, which activates the microphone without transmitting data until communication is established.

3. *Local Processing Unit*

The Local Processing Unit, installed near the patient's bed, receives data from the radar sensor and connects

directly to the microphone and speaker. Its primary functions are to process movement data for emergency detection like falls and to manage bidirectional communication between the patient and caregivers. Additionally, the LPU transmits processed data to the cloud for further analysis and record-keeping. The device, such as the Raspberry Pi, requires a 5V DC power supply. An AC-DC adapter is required to convert wall outlet AC voltage to the 5V DC.

4. Cloud

The cloud platform provides large-scale storage and advanced analysis for patient movement data. It stores patient movement histories, identifies behavioral patterns, and performs anomaly detection, which aids in predicting and preventing potential incidents. Caregivers can access these insights through a web app interface.

5. Web App

The web application provides an accessible interface for nursing home staff, enabling them to monitor patient histories, receive real-time alerts, and communicate directly with patients. Key features include alert notifications and historical data visualizations, empowering caregivers to respond promptly to emergency and anomaly alerts.

- Displays a list of patients with individual access to their movement history and patterns in a graph format.

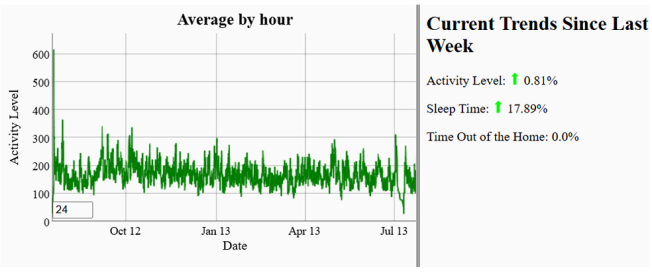

Fig 2. Activity level, sleep time and time out the home

This visualization shows the Activity Level over time, which tracks movement intensity based on data from the motion radar, offering insights into each patient's daily activity trends. The Current Trends Since Last Week section summarizes recent changes in Activity Level, Sleep Time, and Time Out of the Home, calculated from radar and sensor data. This provides caregivers with a general view of any significant changes in behavior, helping to identify potential health concerns or activity patterns.

- Communication integrated with the LPU, enabling caregivers to connect with patients through the speaker for real-time communication.

VI. Performance Specifications

This section outlines performance requirements for each component, spanning the device, edge, and cloud layers. The specifications cover size, performance expectations, connectivity details, energy constraints, and mechanical considerations. data formats, performance expectations, connectivity details, energy constraints, and mechanical considerations.

1. Radar Sensor

The radar sensor will be installed high on a wall, with a minimum of 8-meter detection range to cover a standard room. To minimize interference, it will operate at a frequency band with lower usage, such as 60 GHz. For a discreet installation, the sensor should be compact, with a maximum size of 20 cm x 10 cm x 5 cm. It will transmit data wirelessly to the LPU and it will require direct power from a wall outlet.

2. Communication System (Microphone and Speaker)

Both the microphone and speaker will connect directly to the LPU, ideally drawing power from it. However, if additional power is required, they can also connect to a wall outlet. Compact dimensions are essential to fit neatly into a housing alongside the LPU.

- Microphone: Must provide high clarity, enabling clear detection of human screams and allowing caregivers to understand the patient's speech distinctly.
- Speaker: Requires both quality and adjustable volume, being the volume the most important part, with a sufficiently loud output for patients who may have hearing problems.

3. LPU

The LPU will handle critical event detection (falls) and must be capable of processing these emergency events within 1 second. It will support multiple connections for the speaker and microphone, as well as wireless connectivity with the radar sensor. Powered by a wall outlet, the LPU must be compact enough to fit within the housing with the microphone and speaker.

4. Cloud

Given the importance of elderly care, the cloud platform must be capable of analyzing patient patterns within 1 hour and should support continuous training of the analytical models to enhance performance and accuracy over time.

VII. System Architecture

The system architecture of WaveSafe is designed to provide non-intrusive monitoring for elderly individuals in nursing home environments. It integrates a radar-based motion detection device with a local edge processing unit, facilitating rapid response capabilities while ensuring data privacy. The radar device detects motion parameters, such as presence, speed, and distance, and sends this data to the LPU via Bluetooth Low Energy (BLE) for further processing. The LPU, manages local computations, sound detection, and communication with caregivers, transmitting critical alerts and data to the cloud for long-term storage and analysis. The processing device relies on Wi-Fi for transmitting data to the cloud to ensure seamless integration even in facilities without a wired network infrastructure.

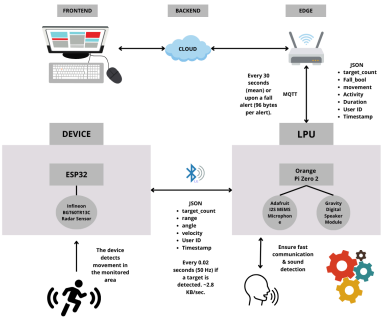

Fig 3. System Architecture

VIII. Implementation Options

This section presents different options currently available in the market for each component in our architecture.

1. *Devices*

The devices are the radar, microphone, and speaker. We have conducted research to determine the best options out there at the moment. We also included research on microcontrollers, as we have not found any radar sensor with incorporated wireless connection.

Below we compare the different alternatives that we contemplate for the Radar sensor of our device:

	Jorjin MM5D91-00	Infineon BGT60TR13C	TI IWRL6432
Unit Price (€/100units)	27.89€	12.21€	14.24€
Frequency Range (GHz)	61.0 - 61.5 GHz	58.0 - 63.5 GHz	57.0 - 64.0 GHz
Detection Range	Up to 10m for human movements	Up to 15m (front facing) Min: 0.2m	Up to 25m
Bandwidth	Narrow 500 MHz	5.5 GHz	7.0 GHz
Field of View (FOV)	Azimuth: ±45º Elevation: ±40º	90	Azimuth: ±120º Elevation: ±80º
Data interface	UART, GPIO	SPI, digital interface	UART, CAN-FD, SPI
Size (mm)	20 x 15 x 2,3 mm	6 x 5 x 0.9 mm	6.45 x 6.45 mm
Power (V/A)	3.6 - 5.5V/ 12 mA	Up to 1.8 V/ 230mA < 5mW	2.7 - 6 V/ 1 - 3 A
Output Signal	I/Q raw data (analog or digital)	Processed data (presence, distance, velocity) or raw I/Q	Processed data (presence, motion, velocity) or raw I/Q

Table I: Radar sensor comparison. The price has been converted from USD $ when necessary, using the rate 1$ = 0.96€.

Among the three radar sensors, each has distinct strengths. The Infineon BGT60TR13C is the most economical and compact, making it ideal for budget-sensitive and space-constrained uses. The TI IWRL6432 offers the longest detection range (up to 25 meters), widest bandwidth, and broadest field of view.. Meanwhile, the Jorjin MM5D91-00, though the most costly, is specifically optimized for human motion detection within 10 meters, making it highly suitable for indoor human presence.

Next is the comparison between different microphones available in the market. We have selected the three best we found for our needs at the lowest cost:

	ReSpeaker 2-Mics Pi HAT	Adafruit I2S MEMS Microphone Breakout	SparkFun Electret Microphone Breakout
Unit Price (€)	16.90 €	7.30 €	8.75 €
Input Type	GPIO (HAT)	I2S	Analog
Frequency Response	100 Hz – 10 kHz	50 Hz – 15 kHz	100 Hz – 10 kHz
Sensitivity	-26 dBFS	-42 dB	-44 dB
Signal-to-Noise (SNR)	59 db	61 db	60 db
Compatibility	Orange (not direct) & Raspberry Pi	Orange (I2S) & Raspberry Pi	Orange (not direct) & Raspberry Pi
Size (mm)	65 x 30	20 x 17	27 x 20
Power (V/A)	5V / 40mA	1.8V – 3.3V / ~1.4mA (standby), ~9mA (active)	3.3V – 5V / 0.5mA

Table II: Microphone Comparison.

Each of these microphone breakout boards has a distinct strength. The ReSpeaker 2-Mics Pi HAT is a strong choice for Raspberry Pi setups, especially when high sensitivity is required for close-range audio capture. The Adafruit I2S MEMS Microphone Breakout stands out for its clarity across a wider frequency rang, with a focus on a high signal-to-noise ratio. Meanwhile, the SparkFun Electret Microphone Breakout offers the simplicity of analog input, making it versatile and easy to integrate.

Below is the comparison for the speaker devices that best meet our needs in a compact size to integrate with the edge and microphone:

	Pimoroni Speaker pHAT	Gravity: Digital Speaker Module	Adafruit Mini Oval Speaker - 8 Ohm 1 Watt
Unit Price (€)	17.75 €	7.13 €	2.90 €
Input Type	I2S	Digital (GPIO)	Wired (solder)
Frequency Response	200 Hz – 20 kHz	Not specified	200 Hz – 20 kHz
Compatibility	Raspberry Pi 3 Model B+, Raspberry Pi 4	Raspberry Pi 3 Model B+, Raspberry Pi 4, Orange Pi Zero2	Raspberry Pi 3 Model B+, Raspberry Pi 4, Orange Pi Zero2
Size (mm)	65 x 30 x 10	40 x 40 x 14	40 x 20 x 5
Power (V)	5V (via GPIO)	2.0 – 5.5V	3.3–5V

Table III: Speakers Comparison.

All three speakers offer distinct advantages. The Pimoroni Speaker pHAT, even though is slightly more expensive, provides a highly integrated solution with a compact design, built-in amplifier, and direct GPIO compatibility. The Gravity: Digital Speaker Module, with its lower price and versatile voltage range, offers a simple and compact design that works well with both Raspberry Pi and Orange Pi boards. Meanwhile, the Adafruit Mini Oval Speaker - 8 Ohm 1 Watt, stands out for its broad frequency range and compact size, providing clear and loud audio output. However, the Adafruit option requires more effort compared to implement.

We compare three different microcontrollers for the radar sensor, focusing on the wireless connectivity:

	ESP32-S3	Nordic nRF52840	STM32WB55
Unit Price (€/100units)	1.72€	4.31€	4.40€
Wireless	BLE 5.0, Wi-Fi 2.4GHz	BLE 5.4, Thread, Zigbee, 802.15.4, ANT and 2.4GHz proprietary protocols	Bluetooth 5.0, IEEE 802.15.4 (compatible with Zigbee and Thread)
Bandwidth	20/40 MHz (Wi-Fi)	1/2 MHz (BLE)	1/2 MHz (BLE)
Maximum Data Rate	150Mbps (for Wi-Fi)	2 Mbps (BLE)	2 Mbps (BLE)
Data interface	UASB, UART, SPI, I2C, I2S, Camera Interface, SD/MMC Host	UART, SPI, TWI (I2C), PDM, I2S, QSPI, USB2.0	UART, SPI, I2C, USB, PDM, SAI
Size (mm)	~18 x 25.5 x 3.1 mm	7 x 7 x 0.85 mm	7 x 7 x 0.85 mm
Power (V/A)	3.3V / 500 mA during peak Wi-Fi transmission	1.7 - 5.5 V / 4.8 mA	1.7 - 3.6 V / ~5.5 mA

Table IV: Microcontroller Comparison.

In the microcontrollers, the ESP32-S3 is the most affordable and provides dual-mode Wi-Fi and BLE 5.0 with a high maximum data rate and wider bandwidth. The Nordic nRF52840 supports more protocols and with a moderate data rate in BLE. The STM32WB55, has a similar price as the Nordic but lacks some connectivity, limited to only low-power, short-range network.

2. LPU

On the LPU side of the device, we've conducted thorough research to determine the most suitable LPU for our needs. The table below presents several options, each with its specifications:

	Orange Pi Zero2	Raspberry Pi 3 Model B+	Raspberry Pi 4
Unit Price (€)	31.20 €	42.95 €	69.95 €
SoC	Allwinner H616	BCM2837B0	BCM2711
CPU	Quad-core Cortex-A53	Quad-core ARM Cortex-A53 a 1,4 GHz	Quad-core ARM Cortex-A72 @ 1.5 GHz
Size (mm)	53 x 60	85,6 x 56,5	85,6 x 56,5
GPU	Mali-G31 MP2	VideoCore IV 400 MHz	VideoCore VI at 500 MHz
RAM	1 GB DDR3	1 GB SDRAM	4 GB LPDDR4
Wireless	Wi-Fi 802.11 b/g/n, Bluetooth 5.0 BLE	Wi-Fi 802.11ac, Bluetooth 4.2 BLE	Wi-Fi 802.11ac, Bluetooth 5.0 BLE
Input pins	26 GPIO	40	40
Current per I/O Pin (mA)	16 mA	16 mA	16 mA
Power (V / A)	5V / 2A (via USB-C or barrel jack)	5V / 2.5A (micro USB)	5V / 2A (USB-C)

Table V: LPU's Comparison

All these LPU's offer diverse options based on performance, connectivity, and cost. The Raspberry Pi 3 B+ model provide affordable solutions with quad-core ARM Cortex processors and basic wireless connectivity through Wi-Fi and Bluetooth. The Raspberry Pi 4, although is more expensive, offers a more powerful CPU, up to 4GB of RAM, faster Wi-Fi and a VideoCore VI GPU. In contrast, the Orange Pi Zero2 offers a compact design and basic connectivity through Wi-Fi 802.11 b/g/n and Bluetooth 5.0 BLE. However, it has fewer GPIO pins, making it less suitable for more demanding applications compared to the Raspberry Pi models.

3. Cloud

For our cloud infrastructure comparison, we evaluated AWS, Azure, and Google Cloud Platform, considering factors like scalability, pricing, and IoT compatibility. The table below highlights their key features, including MQTT support, which varies across platforms and impacts IoT deployment ease. Each provider has strengths in specific areas, making the best choice dependent on your technical needs and integrations.

	Amazon Web Services	**Microsoft Azure**	**Google Cloud Platform**
Price	Pay by the hour or fraction	Pay by the minute	Pay by the minute
Backups	Make 3 copies in the same geographic area	Make 3 copies in the same geographic area	It makes copies in all platforms around the world
Worldwide availability	11 data centers 37 content distribution points	20 data centers 32 content distribution points	4 data centers 160 content distribution points
24/7 support service	Yes	Yes	No
Automatic scalability	Amazon CloudWatch	Autoscaling application block Windows Azure Fabric Controller	BigTable GFS
Marketplace	2,400	707 applications	160 applications

	applications		
Databases	Amazon SSS Amazon Relational DB Service Amazon SimpleDB SQL Server Express SQL Web SQL Server Stand	Relational SQL NoSQL table stores Unstructured blob	Non-relational database (BigTable), optimized for big data and machine learning
Security	26 certifications, including advanced standards	25 certifications, with strong regulatory compliance focus	6 certifications, focused on data analysis and transparency
MQTT Support	AWS IoT Core with built-in MQTT protocol	Azure IoT Hub and Event Hub via Kafka for MQTT integration	HiveMQ for GCP Pub/Sub, replacing Google IoT Core
Server migration	Supports VMware, Hyper-V	Supports Hyper-V servers	No direct support for VMware/Hyper-V

Table VI: Cloud Comparison

AWS, Azure, and Google Cloud Platform (GCP) are the top cloud providers, each with distinct strengths. AWS is known for its extensive range of services, including a wide array of databases, strong security certifications, and native MQTT support via AWS IoT Core, making it ideal for IoT-heavy applications. Azure integrates seamlessly with Microsoft's ecosystem, providing comprehensive support for SQL, NoSQL, and unstructured databases, and offers MQTT capabilities through Azure IoT Hub, catering well to enterprise needs. GCP, while competitive in machine learning and big data analytics, has a more limited database selection and relies on third-party tools like HiveMQ for MQTT functionality, following the deprecation of Google IoT Core.

In terms of global reach, all three offer high availability, with Azure covering the most regions and AWS having the widest content distribution network. Each provider has pricing models based on per-second billing, but GCP often stands out for its cost-efficiency in long-term commitments. Ultimately, the best choice depends on specific project requirements: AWS is often preferred for flexibility, Azure for Microsoft compatibility, and GCP for data analytics and AI-driven projects.

IX. Exploitation of cloud computing

The edge will perform only the necessary computing to instantly identify emergencies. However, the cloud will conduct a more comprehensive analysis of collected data, with insights available on the app. This includes tracking user behavior patterns to identify anomalies, supporting preventive actions for potential risks like predicting falls. Data and insights will also be available to healthcare providers as part of each patient's medical records, aiding long-term care improvements.

X. System implementation

Now that we have analyzed and compared various components, we will describe and define the final WaveSafe product. We will select each options below.

1. Radar Sensor

For the radar sensor, the **Infineon BGT60TR13C** was chosen due to its superior technical specifications and cost-effectivenes. It operates within a frequency range of 58-63.5 GHz, providing up to 15 meters of detection range with precise motion sensing, including velocity and distance measurements. This selection was made because this band typically experiences lower interference, making it ideal for precise motion sensing in room-specific environments. This sensor ensures privacy as it uses non-visual data. Its bandwidth of 5.5 GHz generates an estimated raw data output of 8 Mbps, which can be compressed to 2 Mbps, compatible with BLE 5.0.

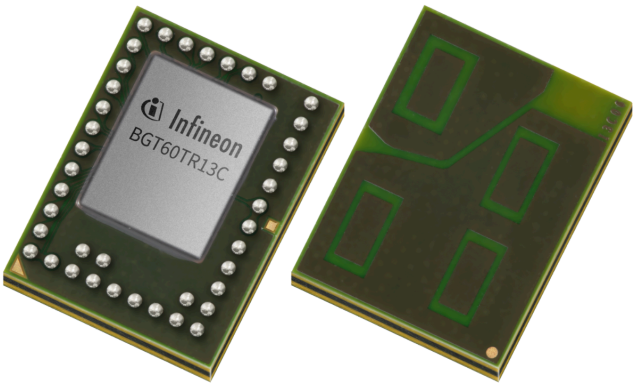

Fig 4. Infineon BGT60TR13C

The Infineon BGT60TR13C radar generates 12.75 KB of raw data per frame (6528 samples, 16 bits each). Processed data is in compact JSON format, typically around 14 bytes plus 6 bytes per additional detected target. This efficient reduction focuses on key metrics like target count, range, and angle, optimizing data for real-time IoT applications.

Compared to alternatives like the TI IWRL6432 and Jorjin MM5D91-00, the Infineon radar strikes the best balance between range (up to 15m) and bandwidth (5.5 GHz) while maintaining affordability. Although the TI IWRL6432 offers a broader range (up to 25m), its higher power consumption and complexity make it less suitable for the compact, room-specific deployment of WaveSafe. The Jorjin MM5D91-00, while optimized for human presence detection, is significantly more expensive and less versatile for broader applications like velocity and distance measurements. The Infineon radar, with its mid-range capabilities, compact size, and adequate motion detection, aligns well with the product's intended use in elderly care environments, where precise room-scale monitoring is sufficient.

2. Local Processing Unit (LPU)

The **Orange Pi Zero 2** was selected due to its cost-efficiency, compact size, and sufficient processing capabilities. While the Raspberry Pi 3 Model B+ and Raspberry Pi 4 offer better overall performance, their higher costs and larger form factors are less suited for a cost-effective, scalable product like WaveSafe. The Orange Pi Zero 2 provides quad-core processing with 1GB DDR3

RAM, meeting the computational needs of the radar sensor and allowing for seamless BLE communication. Its support for Bluetooth 5.0 and Wi-Fi 802.11 b/g/n ensures compatibility with the chosen communication protocols. This LPU is particularly advantageous for WaveSafe's target user base, as it offers robust functionality in a cost-sensitive market without compromising performance. Its compact size and efficient power consumption also simplify installation and integration into home or nursing home environments.

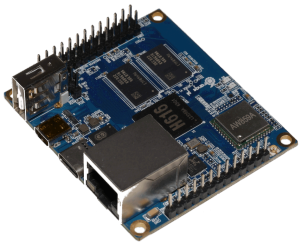

Fig 5. Orange Pi Zero 2

3. Communication System

The **Adafruit I2S MEMS Microphone Breakout** and the **Gravity Digital Speaker Module** were selected to facilitate two-way communication between caregivers and patients. The Adafruit microphone, with its extended frequency range (50 Hz – 15 kHz) and superior signal-to-noise ratio (61 dB), ensures clear voice detection and effective noise filtering, which are vital for capturing emergency calls or distress signals. It outperforms alternatives like the ReSpeaker 2-Mics Pi HAT, which, although designed for the Raspberry Pi, is bulkier and more expensive. Similarly, the SparkFun Electret Microphone Breakout, while slightly cheaper, lacks the Adafruit's digital interface, making it less compatible with the Orange Pi Zero 2.

The Gravity Digital Speaker Module was chosen for its ability to deliver clear, amplified sound tailored to the needs of elderly individuals and those with hearing impairments. Research indicates that age-related hearing loss, known as presbycusis, typically reduces the ability to hear higher frequencies. It also was chosen for its compact size, plug-and-play design, and ability to deliver clear audio output, ensuring effective and non-intrusive communication with patients. Its simple integration with the Orange Pi Zero 2 makes it an ideal choice for WaveSafe, enhancing usability and aligning with the goal of seamless, reliable interactions between caregivers and patients. This combination optimizes performance while keeping costs and complexity low.

Fig 6. Adafruit I2S MEMS Microphone Breakout & Gravity: Digital Speaker Module

4. Cloud

The cloud infrastructure for WaveSafe is built on Amazon Web Services (AWS), chosen for its robust IoT integration, scalability, and advanced data analytics capabilities. To meet the requirements for real-time data storage and retrieval, we selected AWS DynamoDB, a fully managed NoSQL database that minimizes operational overhead. Its integration with AWS Identity and Access Management (IAM) ensures secure access controls, preventing direct exposure to the internet by routing all requests through authorized APIs.

Data transmission between the edge devices and the cloud leverages AWS IoT Core with MQTT protocol, optimized for efficient and reliable communication. AWS EC2 instances handle the bulk of computational tasks, processing incoming data for anomaly detection and system updates. In this setup, predictive analytics and machine learning capabilities are managed by AWS Bedrock, providing real-time insights for caregivers.

For long-term storage and access to multimedia or large files, AWS S3 is utilized, ensuring scalable and cost-effective storage solutions. The system design maintains data privacy and integrity throughout, with all components aligned to deliver a secure, seamless, and responsive experience tailored to WaveSafe's requirements. This integration effectively balances cost, functionality, and ease of use, while maintaining a focus on the specific needs of elderly care environments.

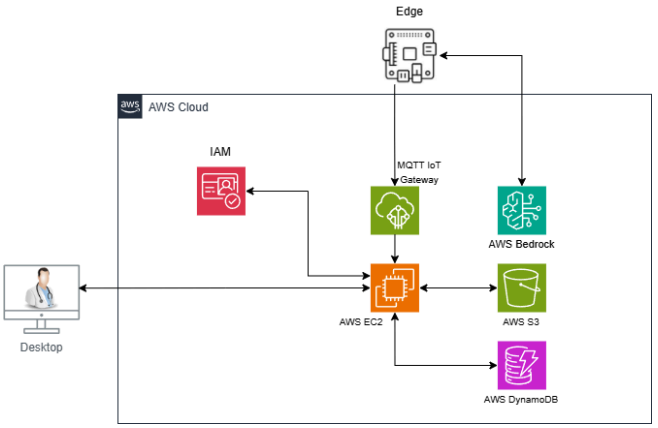

Fig 7. Schematic of the Cloud Infrastructure

5. SoC Selection for Radar Data Compression and Transmission

The ESP32-S3 was chosen for WaveSafe due to its superior balance of functionality, cost, and compatibility with the system's use case. ESP32-S3 offers dual-mode wireless connectivity (Wi-Fi and BLE 5.0) with a BLE data rate of 2 Mbps. In terms of cost, the ESP32-S3 is significantly more affordable at €1.72 per unit (100-unit pricing), compared to €4.31 for the Nordic nRF52840 and €4.40 for the STM32WB55. The ESP32-S3 is also versatile in its

interface support, including SPI and UART, which simplifies integration with the Infineon BGT60TR13C radar sensor. Bluetooth Low Energy (BLE) is preferred over traditional Bluetooth due to its energy efficiency, which is critical for a continuously operating monitoring system. BLE 5.0's 2 Mbps bandwidth aligns with the compressed radar data output.

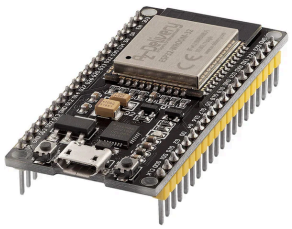

Fig 8. ESP32

6. Power Requirements

The system requires components with distinct power specifications: the radar sensor operates at 1.8V, the ESP32-S3 at 5V, and the local processing unit (LPU) at 5V with higher current demands. Since standard wall outlets supply AC voltage, dedicated AC/DC converters are necessary to provide the appropriate DC voltage levels for each component.

Both the radar sensor and the ESP32-S3 can be powered using a 5V AC/DC adapter. A suitable option is the Zolt 10W 5V 2A Universal Power Supply, which provides an output of 5V at 2A, sufficient for both components. To step down the voltage for the radar sensor to 1.8V, a buck converter (LM2596) can be employed. This configuration allows the ESP32-S3 and radar sensor to share a common power source, simplifying the design and maintaining efficiency.

The LPU, such as the Orange Pi Zero 2, along with peripherals like the microphone and speaker, requires a stable 5V power supply with higher current capacity. An appropriate choice is the LEICKE ULL 5V 3A 15W Universal Power Supply, which provides an output of 5V at 3A, ensuring reliable power delivery to the LPU and its connected components. The microphone can be powered directly through the 3.3V GPIO pin of the LPU.

7. Data Formats

From	To	Data Format	Content	Frequency
Radar Sensor	ESP32-S3	JSON (14 bytes + 6 bytes target)	Processed motion data: target count (integer), range (float), angle (float), velocity (float).	Every 0.01 seconds (100 Hz). ~2 KB/sec for 1 target.
ESP32-S3	Orange Pi Zero 2	JSON (56 bytes)	Processed data: motion data from radar (same as above), User ID (string), and timestamp (ISO 8601 format).	Every 0.02 seconds (50 Hz) if a target is detected. ~2.8 KB/sec.
Orange Pi Zero 2	Cloud	JSON (96 bytes approx)	Processed alerts: boolean for fall detection, movement logs (activity: string, duration: string), User ID, detailed timestamp (ISO 8601).	Every **30 seconds (mean)** or upon a fall alert (**96 bytes per alert**).

Table VII: Data formats

The radar sensor processes its raw data stream internally, which operates at 2 Mbps (~12.75 KB per frame), and reduces it to a compact JSON format for transmission. Each JSON frame consists of 20 bytes per target, including key metrics such as target count (integer), range (float), angle (float), and velocity (float). At a frequency of 100 Hz (every 0.01 seconds), this results in a throughput of approximately 2 KB/sec for 1 target, effectively leveraging BLE 5.0's bandwidth capacity of 2 Mbps.

The ESP32-S3 receives these JSON frames from the radar and aggregates them into 56-byte JSON payloads for transmission to the Orange Pi Zero 2. Each payload includes radar motion data, along with additional context such as User ID (string) and timestamp (ISO 8601). The ESP32-S3 transmits these payloads at 50 Hz (every 0.02 seconds) when a target is detected, resulting in a throughput of approximately 2.8 KB/sec. This falls well within the computational capabilities of the ESP32-S3's dual-core processor.

The Orange Pi Zero 2 processes the incoming data from the ESP32-S3. It performs operations such as:

- Detecting if a fall has occurred (boolean flag).
- Creating movement logs (e.g., activity type, duration).
- Adding metadata, including User ID and detailed timestamp.

The processed data is formatted into 96-byte JSON payloads for transmission to the cloud. These payloads are sent every 30 seconds on average for routine updates or immediately upon detecting a fall. The cloud communication requires negligible bandwidth over Wi-Fi, as routine updates amount to only 96 bytes per 30 seconds, with additional alerts triggered as needed.

XI. Device consumption

We performed a detailed power consumption analysis of WaveSafe's components. Below is the breakdown of power consumption for each device component and the resulting total consumption:

(We always assume an electricity cost of 0.253 €/kWh)

1) Infineon BGT60TR13C Radar Sensor

This radar sensor operates at 1.8V with a typical current consumption of 200mA, translating to a power consumption of 360mW under nominal conditions. It operates in low-power mode (~2.8mA) for most of its duty cycle. This mode reduces energy consumption while maintaining functionality via its FSM, which enables rapid wake-up and accurate movement tracking.

In residential care facilities, the patient is usually within their room during nighttime and sporadically during the day (We estimate 16 hours a day).

- **Voltage (V):** 1.8V
- **Current:** 200mA (active), ~2.8mA (low-power mode)
- **Duty Cycle:** 66% active (16h), 33% low-power

Active Mode:

- Active time: 16 h/day
- Power: 1.8 V×0.2 A=0.36 W
- Energy: 0.36 W×16 h=5.76 Wh

Low Power Mode:

- Low-power time: 8 h/day
- Power: 1.8 V×0.0028 A=0.005 W
- Energy: 0.005 W×8 h=0.04 Wh

5.76Wh+0.04Wh=5.8Wh/day

0.005800kWh×0.253€/kWh≈0.14 cents/day

2) Orange Pi Zero 2

The Orange Pi Zero 2 is the central processing unit for WaveSafe, responsible for data management and system communication. Its power consumption is assessed based on 24-hour operation with continuous processing requirements.

- Voltage (V): 5V
- Current (I): ~2A
- Power: 5V×2A=10W
- Energy: 10W×24h=240Wh=0.24kWh/day
- Cost=0.24kWh/day×0.253€/kWh=0.0607€/day

3) Communication System

The **Adafruit I2S MEMS Microphone Breakout** and the **Gravity Digital Speaker Module** are integral to the two-way communication system in WaveSafe. Their power consumption is calculated based on typical operation for 24 hours per day, with periodic use with standby functionality.

Adafruit I2S MEMS Microphone Breakout

- **Voltage:** 3.3V
- **Current:** 1.4mA (standby) + ~9mA (active)
- **Duty Cycle:** 80% standby, 20% active

Standby Mode:

- **Power**: 3.3V×0.0014A=0.00462W
- **Energy**: 0.00462W×19.2h=0.0887Wh

Active Mode:

- **Power**: 3.3V×0.009A=0.0297W
- **Energy**: 0.0297W×4.8h=0.1426Wh

0.0887Wh+0.1426Wh=0.2313Wh/day

0.0002313kWh×0.253€/kWh≈0.058cents/day

Gravity Digital Speaker Module

- **Voltage:** 5V
- **Current:** ~600mA (active), ~15mA (standby)
- **Duty Cycle:** 10% active, 90% standby
- **Standby Mode:**
  - Power: 5V×0.015A=0.075W5V
  - Energy: 0.075W×21.6h=1.62Wh
- **Active Mode:**
  - Power: 5V×0.6A=3W
  - Energy: 3W×2.4h=7.2Wh

1.62Wh+7.2Wh=8.82Wh/day

0.00882kWh×0.253€/kWh≈0.223cents/day

4) ESP32

The ESP32-S3 is a key component in the WaveSafe system, responsible for bridging data between the radar sensor and the local processing unit. Its power consumption was calculated based on continuous operation with BLE and Wi-Fi functionalities.

- **Voltage (V):** 3.3V
- **Current (I):** ~500mA (peak during Wi-Fi transmission), ~80mA (BLE standby mode)
- **Duty Cycle:** 10% Wi-Fi active, 90% BLE standby

Wi-Fi Active Mode:

- **Active time:** 2.4 h/day
- **Power:** 3.3V × 0.5A = 1.65W
- **Energy:** 1.65W × 2.4h = 3.96Wh

BLE Standby Mode:

- **Standby time:** 21.6 h/day
- **Power:** 3.3V × 0.08A = 0.264W
- **Energy:** 0.264W × 21.6h = 5.7024Wh

Total ESP32-S3 Consumption:

- **Total Energy:** 3.96Wh + 5.7024Wh = 9.6624Wh/day
- **Cost:** 0.0096624kWh × 0.253€/kWh ≈ 0.2447 cents/day

XII. Associated Costs for WaveSafe

To ensure a comprehensive understanding of the costs associated with WaveSafe, the following breakdown has

been detailed. This includes hardware, development, cloud infrastructure, and indirect costs, providing a clear justification for each expense.

Hardware Costs

The hardware costs are based on bulk production of 1000 units, allowing for economies of scale. Prices are extracted from Octopart and DigiKey.

Component	Cost per Unit	Cost per Unit (1000 Units)
Infineon BGT60TR13C Radar Sensor	19.98 €	12.85 €
ESP32-S3 Microcontroller	1.76 €	1.76 €
Orange Pi Zero 2	31.20 €	28.08 €
Adafruit I2S MEMS Microphone	6.46 €	6.46 €
Gravity Digital Speaker Module	5.58 €	5.58 €
Zolt 10W 5V 2A Universal Power Supply	13,52 €	13,52 €
LM2596 DC Converter	1.85 €	1.85 €
LEICKE ULL 5V 3A 15W Universal Power Supply	10.99 €	10.99 €
Total Cost	84.21 €	73.96 €

Table VIII: Hardware Costs

Cloud Infrastructure Costs

To ensure scalability and efficient management of the IoT system for 1000 devices, we employed the AWS cloud platform. The selection of components was based on functionality, cost-effectiveness, and the ability to meet the project's demands. Using the AWS Pricing Calculator, we estimated the monthly and annual costs for the necessary services. Below, we provide a detailed breakdown of the chosen resources, their roles, and the rationale behind each choice:

- **AWS EC2** was chosen as the central compute resource to process real-time alerts, trigger notifications, and manage APIs that allow caregivers and administrators to interact with the system. A t3.large instance was selected because it offers consistent performance with two vCPUs and 8 GB of memory, capable of handling the computational load generated by 1,000 devices. The instance operates at 100% utilization under an on-demand pricing model, ensuring cost-effectiveness without compromising system responsiveness.
- **Amazon S3** provides the necessary storage for photos, audio recordings, and long-term historical movement data generated by the devices. The S3 Standard storage class was selected to store an estimated 24 GB of data per month, with individual file sizes averaging 500 KB. The configuration accommodates approximately 30,000 PUT, COPY, POST, and LIST requests, along with 60,000 GET requests monthly. S3 Standard was chosen for its high durability, availability, and ability to scale with the increasing data demands of the system. Its cost efficiency and seamless integration with other AWS components make it the optimal solution for managing large-scale IoT data.
- **AWS IoT Core** enables real-time, bidirectional communication between devices and the cloud, using the MQTT protocol to facilitate efficient data transmission. Configured for 1,000 devices, the setup supports an average message size of 1 KB, with each device sending approximately 800 messages per month. IoT Core is particularly suited for IoT networks due to its ability to manage large volumes of data and its integration with AWS services such as DynamoDB and EC2. This service ensures that device communication remains reliable and secure, supporting the system's real-time requirements with minimal latency.
- **AWS DynamoDB** is used to store metadata such as alert logs, user activity summaries, and sensor readings. The database was configured with a standard table class, capable of storing 3 GB of data with an average record size of 1 KB. DynamoDB's serverless architecture ensures that it automatically scales to handle the high throughput of data generated by 1,000 devices while maintaining low latency for both read and write operations. This database was chosen for its ability to handle dynamic workloads efficiently, aligning perfectly with the requirements of the monitoring system.
- **AWS Bedrock** is utilized for running machine learning models that perform anomaly detection and predictive analytics, enhancing the intelligence of the monitoring system. The configuration supports the processing of 50 million input tokens and 50 million output tokens per month. This enables the system to analyze data patterns effectively and provide caregivers with actionable insights. Bedrock was selected for its flexibility in deploying and managing pre-trained models, as well as its cost-efficient inference capabilities, making it an ideal component for the system's predictive and analytical tasks.

Using the AWS Pricing Calculator, the total estimated costs for maintaining the cloud infrastructure for 1,000 devices are as follows:

Cloud Service	Monthly Cost	Annual Cost

AWS EC2 (Compute Engine)	66,58 €	798,96 €
AWS S3 (Storage)	0,73 €	8,76 €
AWS IoT Core (Communication)	0,52 €	6,24 €
AWS DynamoDB (Database)	0,87 €	10,44 €
AWS Bedrock	22,5 €	270 €
Total Cost	91,2 €	1094,67 €

Table IX: Cloud Infrastructure Costs

This infrastructure is designed to be cost-effective and scalable, ensuring that the system can grow with future requirements while maintaining high performance and reliability. The use of AWS services provides seamless integration and robust support for the complex demands of an IoT monitoring system.

Development Costs

The development of WaveSafe requires a multidisciplinary team for system design, prototyping, and testing. Costs are calculated based on average monthly salaries for each role in Spain, referenced from Indeed. Work hours are justified at fig. 7.

Role	Skills Required	Salary (€/h)	Work (hours)	Cost (€)
Project Manager	Leadership, task scheduling, resource allocation.	21,88 €/h	1032 h	22580,16 €
Embedded Systems Engineer	Embedded programming, BLE/Wi-Fi, hardware integration.	18,75 €/h	440 h	8250 €
Cloud Architect	Cloud architecture, AWS services, IoT integration.	23,75 €/h	296 h	7030 €
Hardware Engineer	Electronics design, prototyping, AC/DC conversion.	20 €/h	384 h	7680 €
Full Stack Developer	Frontend/backend development, UI/UX design.	21,88 €/h	768 h	16803,84 €
QA Engineer	Testing frameworks, debugging, system validation.	17,5 €/h	516 h	9030 €
Marketing Manager	Marketing strategy, communication, campaign management.	18,75 €/h	1232 h	23100 €
Intern	Being able to complete different tasks, used as support.	7,63 €/h	1200 h	9156 €
Total			5868 h	103630 €

Table X: Work Team Costs

Indirect Costs

Indirect costs cover essential operational aspects such as marketing campaigns, legal compliance, and employee development, ensuring the smooth execution of the project.

Category	Monthly Cost	Annual Cost
Office Space	500 € / month	6.000 €
Equipment Maintenance	300 € / month	3.600 €
Training	400 € / month	4.200 €
Marketing	2000 € / month	24.000 €
Legal and Accounting	800 € / month	9.600 €
Total	4500 € / month	48.000 €

Table XI: Indirect Costs

Final Cost Breakdown

Category	Total Cost
Hardware (1000)	73,96 €
Development	103.630 €
Cloud Infrastructure	1.094,67 €
Indirect Costs (Annual)	48.000 €
Total Estimated Cost	152.798 €

Table XII: Work Team Costs

Estimated Sale Price

Assuming a production of 1000 units, the cost per unit, including development and indirect costs, is:

- Per Unit Cost: 152.798 € / 1000 = 152,798 €
- Sale Price (30% Profit Margin): 199.99 €
- Break-Even Point: 152798 € / 199.99 € - 73.96€ = 1212 units

XIII. Task Scheduling

To complete the IoT System for Monitoring of Elderly People, the project is divided into five main phases: **Planning and Requirements**, **Development**, **Integration and Testing**, **Certification**, and **Go-to-Market Strategy**. These stages include tasks related to the design, implementation, testing, and market launch of the system.

Each phase is planned with a detailed schedule to ensure efficient resource allocation and timely delivery. The project spans **196 days, from January 2, 2025, to October 8, 2025**. Below is a summary of each phase:

Planning and Requirements (15 days):

- This phase sets the foundation by defining clear objectives and deliverables, ensuring alignment among stakeholders, and creating a detailed project schedule. The hardware engineer and project manager collaborate to determine the project's technical scope, while the marketing manager analyzes the needs of caregivers and residential facilities to ensure the product addresses critical pain points. A comprehensive project plan is then developed, integrating input from all relevant resources to establish milestones and allocate responsibilities effectively.

Development (120 days):

- Development is the core of the project, focused on creating the core functionalities of WaveSafe. A prototype is developed by the embedded systems and hardware engineers, integrating the radar, ESP32, and Orange Pi Zero 2 components. Hardware components are thoroughly implemented and tested to ensure operational readiness. Simultaneously, embedded software is developed to handle radar data processing and communication. Backend development and cloud infrastructure creation follow, ensuring a robust system for data handling and analytics. The frontend web interface is then designed with usability in mind, providing caregivers and facilities with an intuitive platform for monitoring and interaction.

Integration and Testing (46 days):

- In this stage, hardware and software components are brought together and thoroughly validated. Engineers ensure seamless integration of all elements, while QA resources conduct rigorous testing of individual modules and the overall system. This phase includes system integration testing to identify and resolve any functional or performance issues. User acceptance testing involves caregivers and facility staff, whose feedback is critical in refining the product to meet real-world needs effectively.

Certification (90 days):

- This phase is crucial for ensuring WaveSafe complies with industry standards such as ISO 13485 (medical devices) and CE certifications. Documentation and compliance testing are carried out by the project manager and QA engineer, ensuring the product meets safety and quality benchmarks essential for deployment in residential care environments.

Go-to-Market Strategy (151 days):

- The final phase ensures a successful introduction of WaveSafe to the market. Marketing managers develop targeted strategies to position the product effectively, highlighting its benefits for caregivers and residential facilities. Distribution channels and sales networks are established, ensuring efficient delivery to potential users. The product is officially launched through a coordinated event, leveraging the combined efforts of the marketing team and project management to maximize market impact.

Below is the complete task list with the amounts of day given to completion, the resources, and the dependencies between tasks:

Nº	Task Name	Days	Resources	Dependencies
1	**Planning and Requierements**	**15**		
2	Define project objectives and deliverables	5	Hardware Engineer, Project Manager	
3	Conduct stakeholder analysis	3	Marketing Manager, Project Manager	2
4	Develop detailed project plan and schedule	7	Project Manager, QA Engineer	3
5	**Development**	**120**		
6	Develop prototype	30	Embedded Systems Engineer, Hardware Engineer	1
7	Implement hardware components	10	Hardware Engineer, QA Engineer[50	6

			%], Intern	
8	Develop emebedded software for radar integration	24	Cloud Architect, Embedded Systems Engineer	6
9	Backend development	35	Full Stack Developer	6
10	Create cloud infraestructure	25	Cloud Architect, Full Stack Developer	6
11	Develop Web Page Frontend	30	Full Stack Developer	10
12	**Integration and Testing**	**46**		
13	Integrate hardware and software components	8	Embedded Systems Engineer, Hardware Engineer	5
14	Conduct unit testing of individual modules	5	Embedded Systems Engineer, Intern	13
15	Perform system integration testing	10	Full Stack Developer, QA Engineer[45 %]	14
16	Execute user acceptance testing	23	QA Engineer[15 %], Project Manager	15
17	**Certification**	**90**		
18	Documentation and testing for ISO and CE	90	Project Manager, QA Engineer[50 %], Intern	5SS, 12FF+5 days
19	**Go To Market Strategy**	**151**		
20	Develop marketing strategy and positioning	100	Marketing Manager	5
21	Establish distribution and sales channels	50	Marketing Manager, Intern	20
22	Official product launch	1	Marketing Manager, Project Manager	17, 21

Table XIII: Work Team Costs

The tasks are planned to run in parallel where feasible to optimize the timeline. For instance, backend development and the creation of the cloud infrastructure overlap with the prototype development phase, while marketing strategy development begins during the final testing stages.

XIV. Business Model

Value Proposition

WaveSafe addresses the challenges of elderly care by providing a monitoring system that:

- Ensures privacy through radar-based motion detection, avoiding the use of cameras or wearables.
- Offers real-time alerts and predictive analytics to detect anomalies such as falls or prolonged inactivity.
- Delivers cost-effective solutions with scalable deployment options for various care environments.
- Reduces caregiver stress by enabling remote monitoring with actionable insights via a web application.

Revenue Streams

Hardware sales:

- Initial purchase of devices, including the radar unit, local processing unit, and communication peripherals.
- Price per unit set at €199.99, achieving a competitive edge while maintaining a profit margin of 30%.

Subscription model:

- Monthly fees for cloud storage, real-time alerts, and predictive analytics.
- Pricing starts at €10/month per unit, tailored for small-scale deployments. For large-scale ones, bundles are considered.

Target Customers

1. Nursing homes and assisted living facilities: Institutions seeking to improve care quality while optimizing operational costs.
2. Family caregivers: Families caring for elderly individuals at home who require remote monitoring tools.

Scalability and Expansion

- Initial launch focusing on Spain as a pilot market.
- Mid-term expanding into other European countries with aging populations and established healthcare systems.
- Targeting North America and Asia for long-term growth, leveraging partnerships and localized manufacturing.

XV. Final conclusions

We can confirm that WaveSafe fulfills the objectives outlined in the early phases of development. The

components were selected to prioritize privacy, energy efficiency, and affordability, aligning with the goal of providing non-intrusive monitoring for elderly individuals. It ensures a robust solution capable of detecting anomalies without relying on cameras or wearables, addressing key limitations of existing market options.

The sale price of €199.99 per unit provides a feasible entry point into the market with a profit margin of 30%. To cover the associated costs, including hardware, development, and marketing, a minimum of 1212 units would need to be sold to break even. While this is a challenging target, additional income streams, such as subscriptions for predictive analytics and caregiver tools, could significantly enhance profitability and reduce dependency on hardware sales alone.

WaveSafe brings an innovative and practical solution to a growing market segment. Current competitors often rely on intrusive solutions like cameras or wearables, which can face resistance from users. WaveSafe addresses these concerns by offering a discreet, radar-based monitoring system that balances technical performance with usability and accessibility.

This project has also been an opportunity to apply and expand our knowledge across a range of fields, from hardware design to cloud integration and market strategy. It has allowed us to design a scalable and market-ready IoT solution that contributes meaningfully to improving elderly care. While challenges remain, the foundation laid by this project positions WaveSafe as a competitive and impactful product in the IoT healthcare sector.

XVI. Author's contributions

This document was created by Adrián Gonzalez, Adrian García, Gabriel Juan, and Youssef Cahouach. The work was distributed fairly among the team, with all members actively participating in each section. However, some parts were completed in parallel to make the most of the team's varied skills and expertise.

Adrián González originated the concept of WaveSafe and has played a central role in organizing the project and communicating its progress. Drawing on his experience with similar projects, he has ensured the integration of feedback, maintained the documentation up to date, and overseen key decisions across all phases of development. He has been instrumental in coordinating the team, setting priorities, and driving the project's vision forward.

Youssef Cahouach and Gabriel Juan focused primarily on the cloud-related aspects of the project, leveraging their extensive experience with AWS. They were responsible for designing the cloud infrastructure, implementing predictive analytics, and ensuring the system's scalability and security.

Adrian García specialized in device compatibility and the overall system architecture. He designed the framework to ensure seamless communication between devices, edge processing units, and the cloud. His work also ensured the selected components worked together effectively and met the system's performance requirements.

Despite these individual areas of focus, the entire team collaborated to review, refine, and align each section. This ensured the project maintained a cohesive structure and that everyone had a clear understanding of all its elements.

All authors participated in drafting and reviewing the final project, contributing to its refinement and ensuring the accuracy and relevance of the research. This collaborative effort resulted in a comprehensive and scalable solution for elderly care monitoring.

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	Task Name	Duration	Start	Finish	Predecessors	Resource Names	Work	Cost
1	**IoT System for Monitoring of Elderly People**	**196 days**	**Thu 02/01/25**	**Wed 08/10/25**			**5.868 hrs**	**103.630,00 €**
2	**Planning and Requierements**	**15 days**	**Thu 02/01/25**	**Thu 23/01/25**			**240 hrs**	**4.855,60 €**
3	Define project objectives and deliverables	5 days	Thu 02/01/25	Thu 09/01/25		Hardware Engineer;Project Manager	80 hrs	1.675,20 €
4	Conduct stakeholder analysis	3 days	Fri 10/01/25	Tue 14/01/25	3	Marketing Manager;Project Manager	48 hrs	975,12 €
5	Develop detailed project plan and schedule	7 days	Wed 15/01/25	Thu 23/01/25	4	Project Manager;QA Engineer	112 hrs	2.205,28 €
6	**Development**	**120 days**	**Fri 24/01/25**	**Tue 15/07/25**			**1.712 hrs**	**35.688,80 €**
7	Develop prototype	30 days	Fri 24/01/25	Fri 07/03/25	2	Embedded Systems Engineer;Hardware Engineer	480 hrs	9.300,00 €
8	Implement hardware components	10 days	Mon 10/03/25	Fri 21/03/25	7	Hardware Engineer;QA Engineer[50%];Intern	120 hrs	1.805,20 €
9	Develop emebedded software for radar integration	24 days	Mon 10/03/25	Thu 01/05/25	7	Cloud Architect;Embedded Systems Engineer	192 hrs	4.080,00 €
10	Backend development	35 days	Wed 28/05/25	Tue 15/07/25	7	Full Stack Developer	280 hrs	6.126,40 €
11	Create cloud infraestructure	25 days	Mon 10/03/25	Fri 11/04/25	7	Cloud Architect;Full Stack Developer	400 hrs	9.126,00 €
12	Develop Web Page Frontend	30 days	Mon 14/04/25	Tue 27/05/25	11	Full Stack Developer	240 hrs	5.251,20 €
13	**Integration and Testing**	**46 days**	**Wed 16/07/25**	**Wed 17/09/25**			**500 hrs**	**9.661,36 €**
14	Integrate hardware and software components	8 days	Wed 16/07/25	Fri 25/07/25	6	Embedded Systems Engineer;Hardware Engineer	128 hrs	2.480,00 €
15	Conduct unit testing of individual modules	5 days	Mon 28/07/25	Fri 01/08/25	14	Embedded Systems Engineer;Intern	80 hrs	1.055,20 €
16	Perform system integration testing	10 days	Mon 04/08/25	Fri 15/08/25	15	Full Stack Developer;QA Engineer[45%]	84 hrs	1.680,24 €
17	Execute user acceptance testing	23 days	Mon 18/08/25	Wed 17/09/25	16	QA Engineer[15%];Project Manager	208 hrs	4.445,92 €
18	**Certification**	**90 days**	**Thu 22/05/25**	**Wed 24/09/25**			**1.800 hrs**	**27.547,20 €**
19	Documentation and testing for ISO and CE	90 days	Thu 22/05/25	Wed 24/09/25	6SS;13FF+5 day	Project Manager;QA Engineer[50%];Intern	1.800 hrs	27.547,20 €
20	**Go To Market Strategy**	**151 days**	**Mon 10/03/25**	**Wed 08/10/25**			**1.616 hrs**	**25.877,04 €**
21	Develop marketing strategy and positioning	100 days	Mon 10/03/25	Tue 29/07/25	7	Marketing Manager	800 hrs	15.000,00 €
22	Establish distribution and sales channels	50 days	Wed 30/07/25	Tue 07/10/25	21	Marketing Manager;Intern	800 hrs	10.552,00 €
23	Official product launch	1 day	Wed 08/10/25	Wed 08/10/25	18;22	Marketing Manager;Project Manager	16 hrs	325,04 €

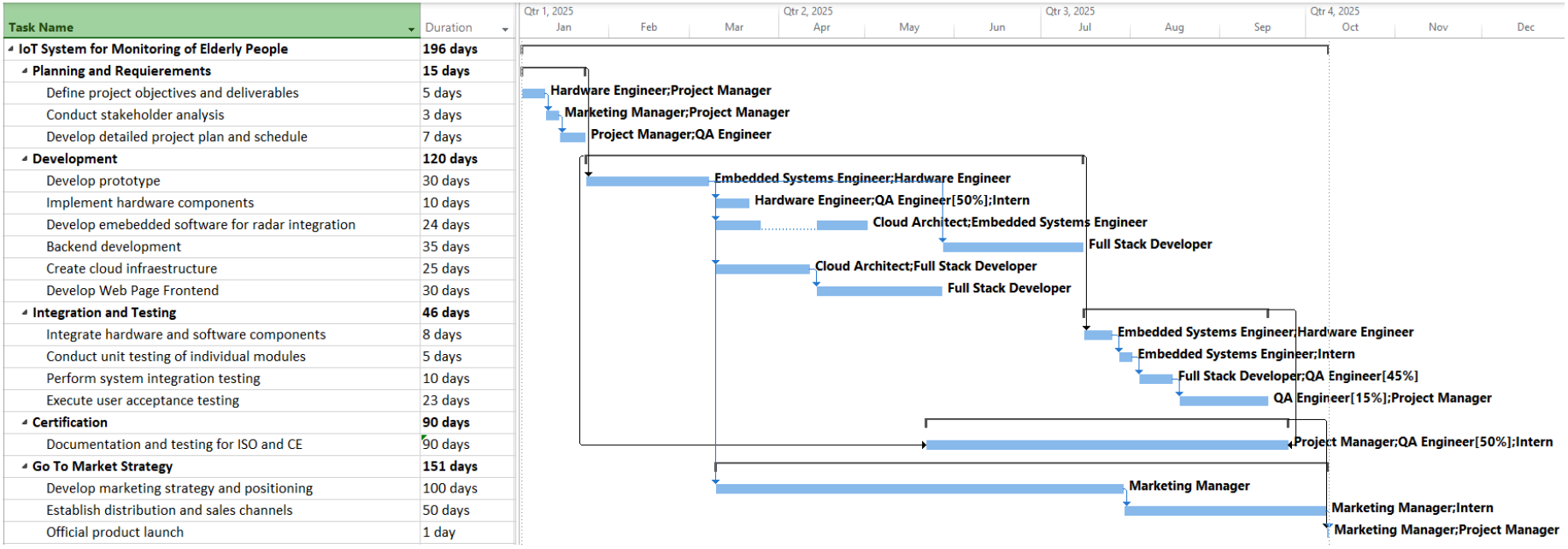

Fig 9 & 10. Task Scheduling and GANTT