Software Requirements Specification

for

WTag

Version 1.18.4.1

Prepared by

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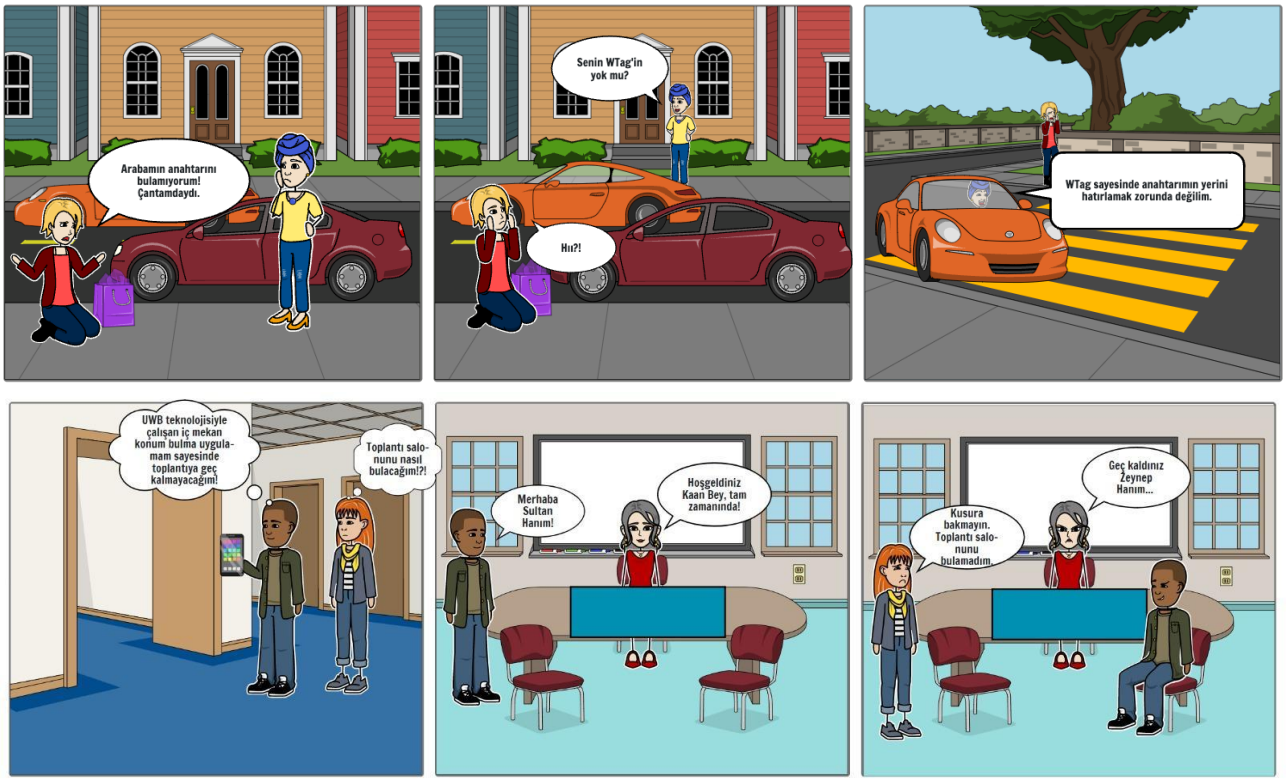
Revision History

Name	Date	Reason For Changes	Version
Version 1	30/04/2023	Initialization	1.0
Version 2	07/06/2023	Final Report	1.18.4.1

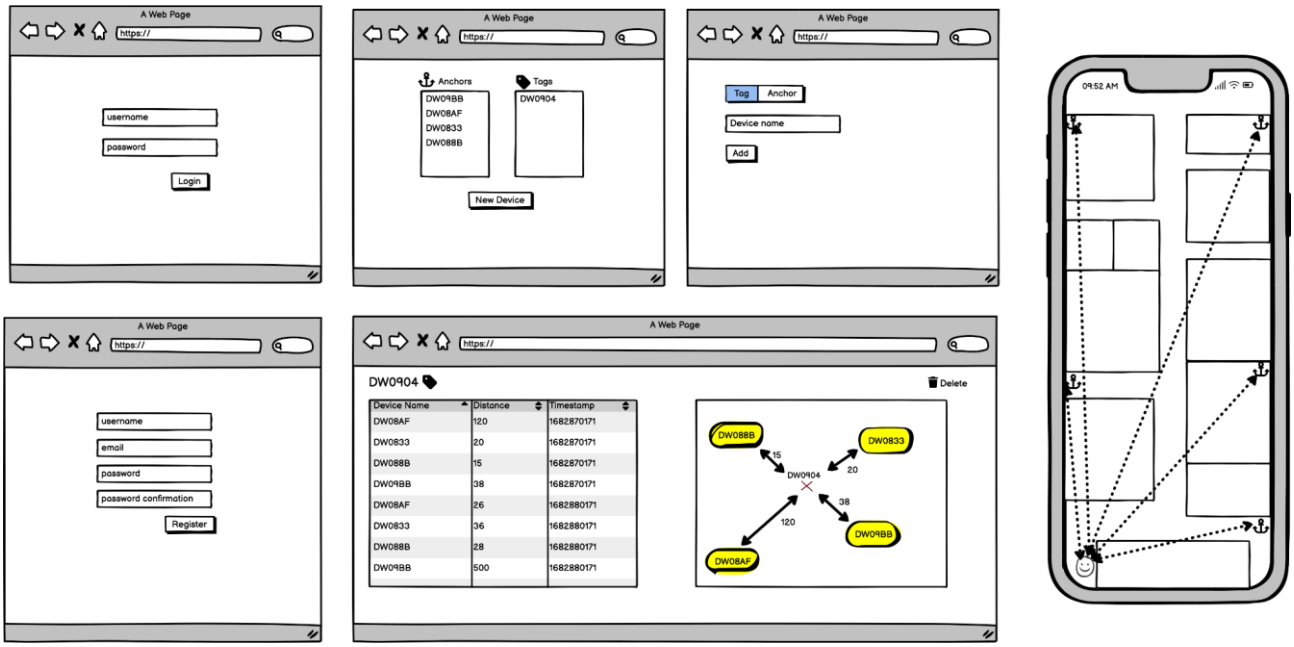
1. Introduction

Indoor location and distance detection technology has several purposes, including indoor navigation, asset tracking, safety and security, personalization, and energy efficiency. This technology enables users to navigate and interact with indoor environments more efficiently and effectively, while also improving safety and security measures. It can be used to track the movement of assets and people, provide personalized services and recommendations, and optimize energy usage within indoor environments.

2. Conceptual Design (Storyboards)



3. Mockup



4. Overall Description

4.1 Product Perspective

The indoor location and distance detection project using UWB technology involves careful consideration of the product functions, user characteristics, constraints, assumptions and dependencies, and interfaces, to ensure the system is effective, efficient, and easy to use.

4.2 Product Functions

The indoor location and distance detection system using UWB technology should be designed to perform a range of functions, including accurate location tracking, distance measurement, asset tracking, and navigation.

4.3 User Classes and Characteristics

The target users include building owners and managers, security personnel, facility staff, customers or visitors, and other stakeholders who require indoor location and distance information for a range of purposes.

Some key user characteristics to consider when designing such a system includes:

Technical expertise: The system should be designed to cater to users with varying levels of technical expertise, from expert users who may require advanced features and customizations, to novice users who may require simple and intuitive interfaces.

Accessibility: The system should be designed to cater to users with varying levels of physical ability, including those with visual or hearing impairments, or mobility issues. The system should include accessibility features, such as voice-guided navigation, large text displays, and support for assistive devices.

Security: The system should be designed to cater to users who require secure access to location and distance information, such as building owners and security personnel. The system should include robust security features, such as user authentication, data encryption, and secure communication protocols.

Customization: The system should be designed to cater to users who require customized features and configurations, such as building owners and managers who may require specific floor plans, zones, or location-based rules. The system should include customization features, such as a flexible API, and support for user-defined rules and triggers.

Ease of use: The system should be designed to cater to users who require a simple and intuitive interface, such as customers or visitors who may require basic location and distance information. The system should include easy-to-use features, such as a user-friendly mobile app or web interface, and clear instructions or tutorials.

4.4 Operating Environment

The system must be designed to operate in a variety of indoor environments, which may have different layouts, structures, and materials that can affect UWB signals.
Additionally, the system must be designed to operate in environments with varying levels of interference from other wireless devices, such as Wi-Fi networks, Bluetooth devices, and other UWB systems.
The operating environment also has implications for the system's hardware and infrastructure requirements. The system may require additional hardware components or infrastructure to operate in larger indoor environments or in environments with complex layouts or structures.
The system must also be designed to accommodate changes in the operating environment, such as the addition or removal of obstacles or changes in the wireless signal environment.

4.5 Design and Implementation Constraints

In the indoor location and distance detection project using UWB technology, the design and implementation constraints include the need for accurate and reliable location detection, scalability, flexibility, robust hardware and software infrastructure, compliance with industry standards and regulations, and user-friendliness. These constraints require careful consideration

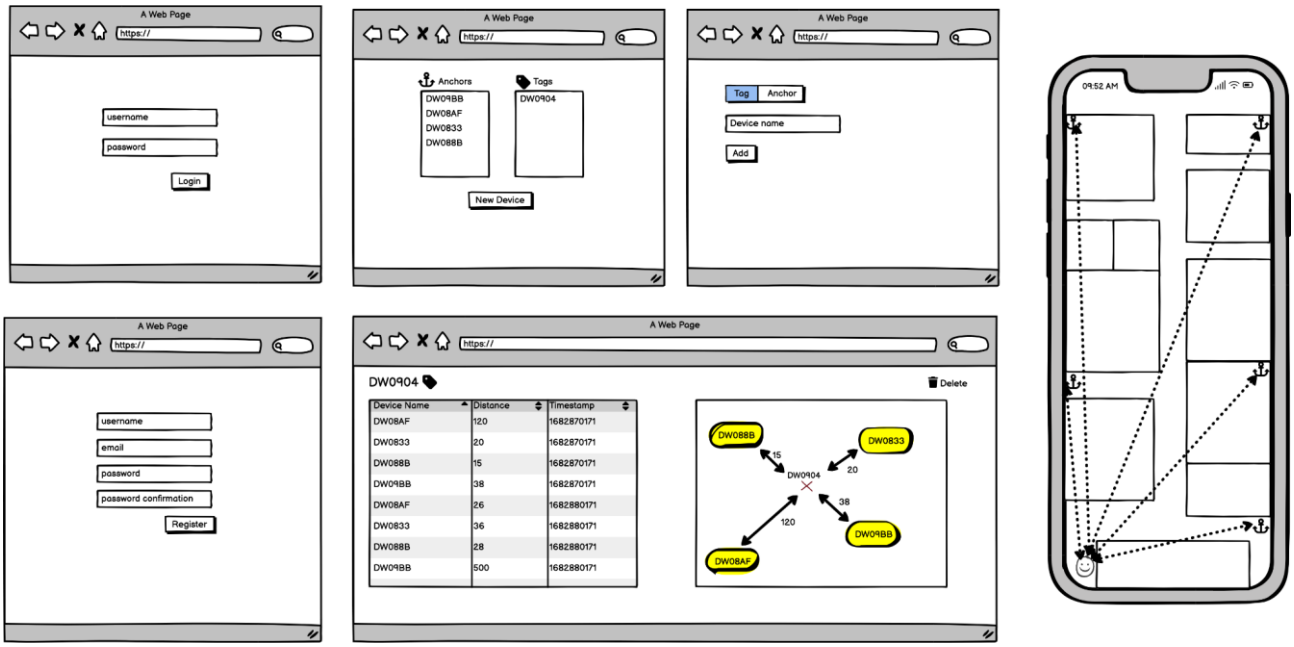
of the UWB technology used, system architecture, signal processing capabilities, security features, and user interface.

4.6 Assumptions and Dependencies

The system should be designed with an understanding of the assumptions and dependencies that underpin its operation, including the availability of infrastructure such as beacons and anchors, as well as the need for other systems to interact with the UWB-based indoor location and distance detection system.

5. External Interface Requirements

5.1 User Interfaces



There are authentication pages in the system. Any customer can register and log into the system using these pages. After authentication, the system displays anchors and tags to clients. Users can add tags or anchors with a simple UX. They can see the distance between the added tags and anchors cumulatively.

5.2 Hardware Interfaces

The hardware interfaces for indoor location and distance detection using UWB technology typically involve UWB chips. These components are often integrated into electronic devices

such as smartphones, wearables, or other IoT devices, and communicate with the software system through standardized communication protocols.
For example, UWB chips may be embedded in a smartphone or wearable device and communicate with the device's operating system via standard communication protocols such as Bluetooth or Wi-Fi.
DWM1001 chip is connected to an antenna or sensor, which allows it to transmit and receive UWB signals and accurately measure the distance between devices.

5.3 Software Interfaces

The system uses a cloud-based mongo database. With the HiveMQ plugin, it subscribes to MQTT messages and records the relevant messages in the database by capturing the events that will come from there. In this way, the data will be stored on the database. This stored data can be visualized on a 2D plane with a web based application.

5.4 Communications Interfaces

ESP8266 module communicates with the cloud data storage system via MQTT messages.
DWM1001 communicates with ESP8266 module via SPI protocol with the module nRF24L01.

6. System Features

6.1 Location Detection

This feature allows the system to determine the precise location of a user within a defined indoor space.

To accomplish this feature, the system uses a combination of UWB signals and signal processing algorithms to accurately triangulate the position of a user. This information can then be used to provide various services or applications, such as indoor navigation, or asset tracking. The ability to detect the location of a user within the defined indoor space is a critical feature for any indoor location and distance detection system using UWB technology, as it forms the foundation for many of the other functions and services provided by the system.

The algorithm uses these methods below:
1. Signal Strength Based Schemes
2. Time Based Schemes
a. Time of Flight
b. Time Difference of Arrival
c. Phase Difference of Arrival

6.2 Distance Calculation

Calculating the euclidean distance between two tags or a specified location with the data obtained in the above feature.

6.3 Data Collection and Storage

This system feature highlights the ability of the indoor location and distance detection system using UWB technology to communicate with a Mongodb and HiveMQ plugin to store and retrieve user data. This means that the system must be able to establish a reliable and secure connection with both the Mongodb and HiveMQ plugins to ensure seamless data transfer. This feature is essential for the system to store and retrieve user data such as user profiles, location data, and other relevant information. By having this feature, the system can efficiently manage user data and provide a more personalized and reliable service to the users.

6.4 Communication

The ability of the system to provide location and distance information to a user's device is a system feature that enhances the user experience. It enables the user to access real-time information about their location and distance from other objects or users within the defined indoor space. This feature requires the system to have reliable and accurate communication capabilities that allow for seamless transmission of information from the system to the user's device. Providing real-time location and distance information to a user is also an important aspect of the system's functionality, as it allows users to make informed decisions and take appropriate actions based on their current location and distance from anchors and tags.

7. Requirements

7.1 Business Requirements

1. The system must be affordable and cost-effective to implement.
2. The system must be accurate in its location and distance measurements.
3. The system must be easy to use and require minimal training for users.
4. The system must be scalable and able to handle multiple users simultaneously.
5. The system must be compatible with a variety of devices, such as smartphones and laptops.

7.2 System Requirements

1. The system must use UWB technology to accurately track the location of a user.
2. The system must use UWB technology to accurately calculate the distance between the user and other objects.
3. The system must be able to communicate with a central server or database to store and retrieve user data.

4. The system must be able to communicate with a user's device to provide location and distance information.
5. The system must be able to handle data encryption and user authentication to ensure security.

7.3 Functional Requirements

1. The system must be able to detect the location of a user within the defined indoor space.
2. The system must be able to calculate the distance between the user and other objects within the defined indoor space.
3. The system must be able to communicate with a central server or database to store and retrieve user data.
4. The system must be able to provide location and distance information to a user's device.
5. The system must be able to provide real-time location and distance information to a user.

7.4 Non-functional Requirements

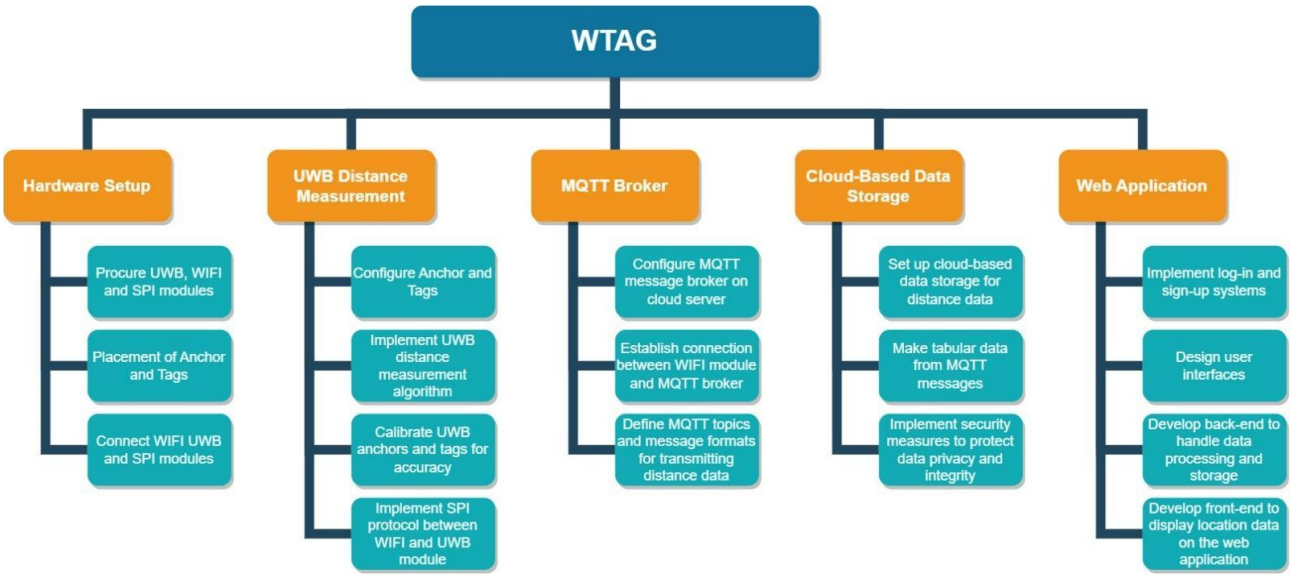
1. The system must have a high degree of accuracy in its location and distance measurements.
2. The system must be able to handle a large number of users simultaneously.
3. The system must be able to operate in various indoor environments, such as offices, warehouses, and hospitals.
4. The system must be able to handle data encryption and user authentication to ensure security.
5. The system must have a low latency time and respond quickly to user requests.

7.5 Constraints

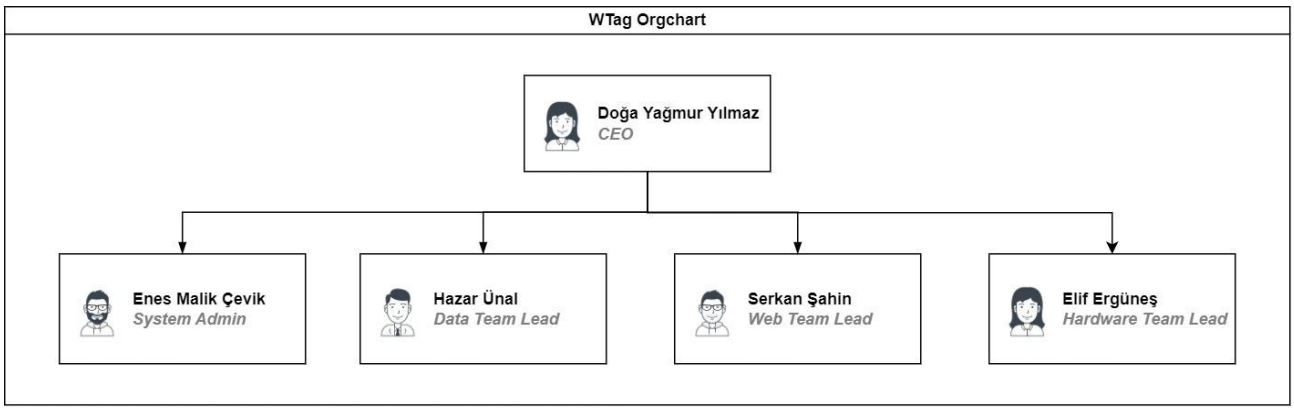
1. The system must comply with UWB regulations and guidelines.
2. The system must be able to operate with minimal interference from other wireless technologies.
3. The system must be designed to minimize power consumption to extend battery life for users' devices.
4. The system must be designed to work with existing infrastructure, such as Wi-Fi and Bluetooth networks.
5. The system must be designed to be easily deployable and require minimal maintenance.

8. Functional Decomposition

6.



9. Organizational Chart



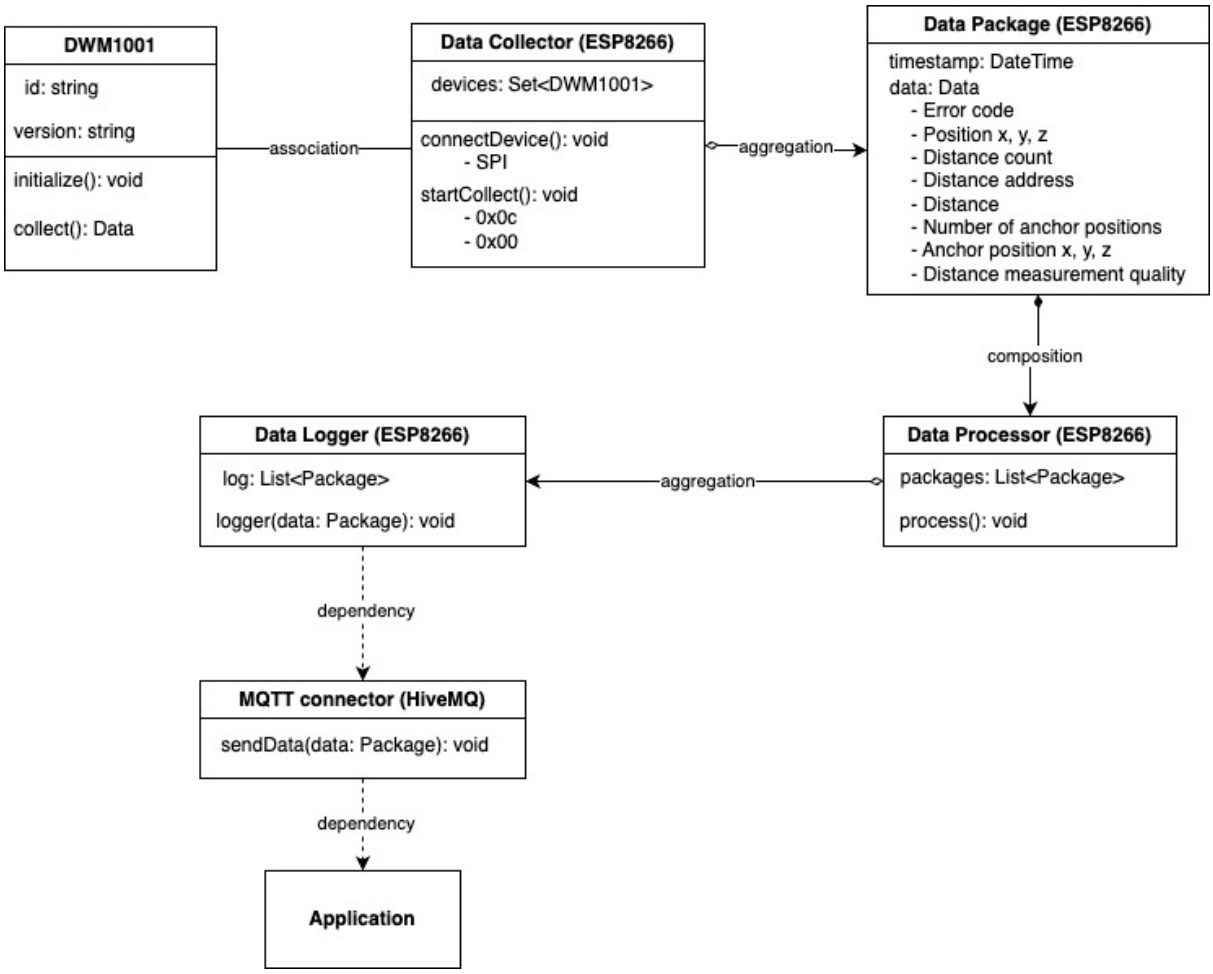
10. Tasks

- Configure anchor and tag
- Implement distance algorithm
- Plot distance via serial plotter and calibrate anchor-tag
- Send distance data and device names to WIFI module via SPI protocol
- Define MQTT topics and message formats
- Make MongoDB database
- Configure MQTT plugin HiveMQ in MongoDB
- Send MQTT message to cloud-based data storage via WIFI module
- Login and signup system for web applications

- User interfaces
- Make database subscribe to MQTT topic via web application to add and remove anchors-tags
- Visualize distances between anchors-tags on a 2D plane for each tag.

11. Gantt Chart

12. Class Diagram



13. User Story

Title: **Retrieve User Location within the Building**	**Priority**: P0	**Estimate:** 3 months	**Title:** **Calculate Distance from User Location to Specific Points of Interest**	**Priority**: P1	**Estimate:** 1 month
User Story: As a user I want access a website where I can input my details and retrieve my location within the building So that I can share my location information			**User Story:** As a user I want I want to access a website where I can retrieve the distance between my location within the building and specific points of interest So that I can find the location that I desire to go		
Acceptance Criteria: -The website should provide a user-friendly interface with input fields for the user's details (e.g., name, ID, or room number). -Upon submitting the details, the website should accurately determine and display the user's location within the building. -The user's location should be based on the distance data calculated using the DWM1001 chips and transmitted via the ESP8266 module. -The website should provide clear instructions on how to interpret the user's location within the building. -The website should be responsive and accessible from various devices and browsers. -Error handling should be implemented to address any issues that may arise during the user location retrieval process. The system should ensure the security of user data and protect user privacy.			**Acceptance Criteria:** -The website should display a list of predefined points of interest within the building. -Upon selecting a specific point of interest, the website should accurately calculate and display the distance between the user's location and the selected point. -The distance calculation should be based on the distance data calculated using the DWM1001 chips and transmitted via the ESP8266 module. -The website should provide clear instructions on how to interpret and understand the distance data. -The website should be responsive and accessible from various devices and browsers. -Error handling should be implemented to handle any issues that may occur during the distance calculation process. -The system should ensure the security of user data and protect user privacy.		

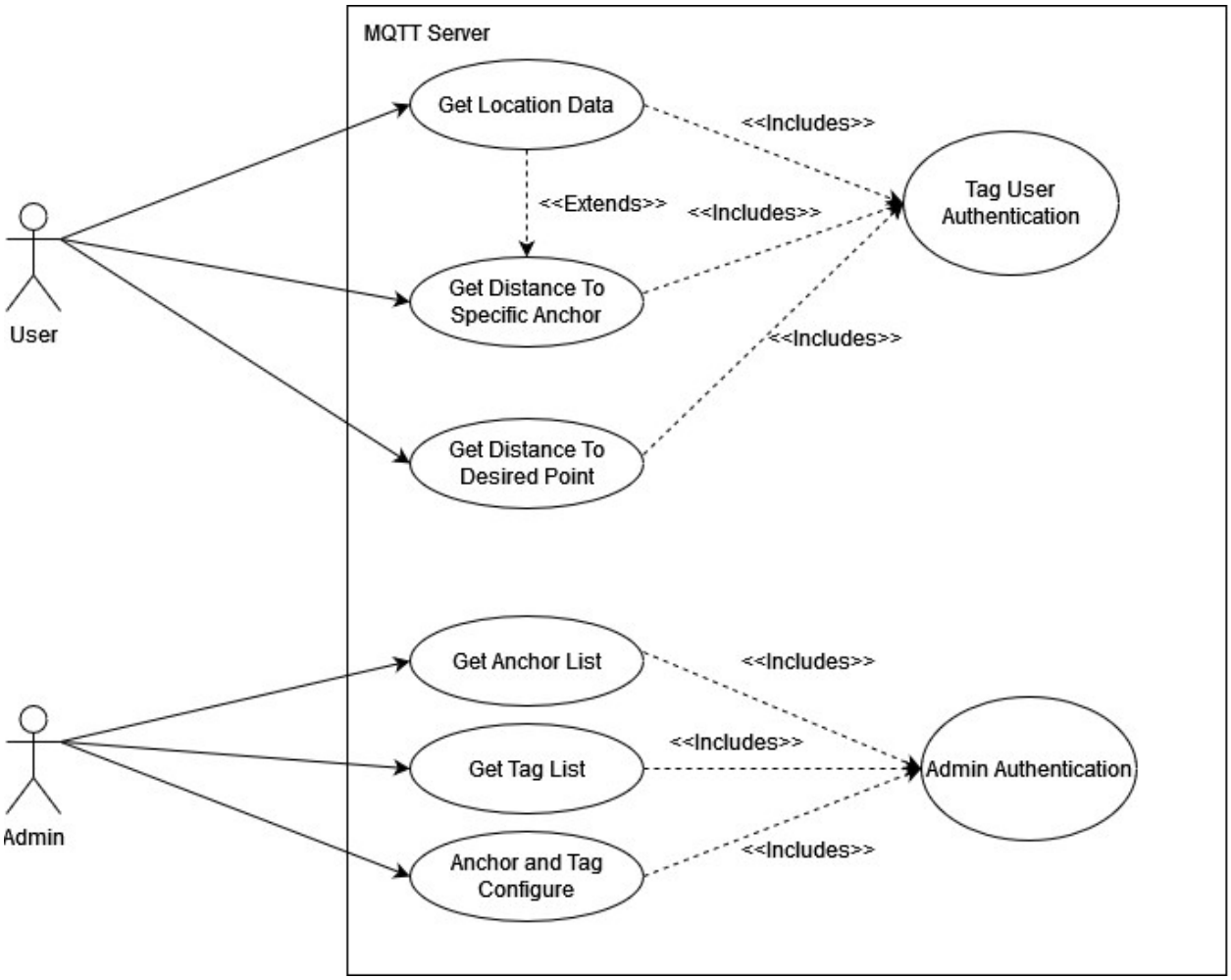
Title: **User Registration and Authentication for Website Access**	**Priority**: P3	**Estimate:** 1 month	**Title:** **Admin Control for Managing Tag and Anchor Data**	**Priority**: P2	**Estimate:** 1 week
User Story: As a user I want to register and authenticate myself to access the website for location retrieval and distance calculation. So that only I can access my location data as a user			**User Story:** As an administrator I want to access a website where I can modify the tag and anchor data used for distance calculations So that I can rearrange the anchor locations and decide which modules I will use as tag or anchor		
Acceptance Criteria: -The website should provide a user registration interface where new users can create an account by providing their details. -The registration process should include validation to ensure the accuracy and integrity of the user's information. -After successful registration, users should be able to log in to the website using their credentials. -The authentication process should validate the user's credentials and grant access to the appropriate features and data. -In case of invalid credentials, appropriate error messages should be displayed to the user. -The website should provide secure password storage mechanisms, such as hashing and salting, to protect user accounts. -The user authentication process should be reliable and efficient, allowing users to access their personalized data securely. -The website should include a "Forgot Password" feature that allows users to reset their passwords in case of forgotten credentials. -Error handling should be implemented to handle any issues that may occur during the registration and authentication processes. -The system should ensure the security of user data and protect user privacy.			**Acceptance Criteria:** -The website should have an admin interface that requires authentication to access. -Upon successful authentication, the admin should be able to view and modify the tag and anchor data used in the distance calculations. -The admin interface should provide options to add, remove, or update tag and anchor information easily. -Changes made to the tag and anchor data should be reflected accurately in the distance calculations. -The website should provide clear instructions and guidance on how to modify the tag and anchor data. -The website should be responsive and accessible from various devices and browsers. -Error handling should be implemented to handle any issues that may occur during the admin data modification process. -The system should ensure the security of admin data and protect against unauthorized access or modifications.		

Title: **Data Logging and Audit Trail for User and Admin Activities**	**Priority**: P4	**Estimate:** 1 month
User Story: As an administrator I want to enable data logging and maintain an audit trail of user and admin activities on the website So that the system can work properly and securely and provide data for later usage of enhancement and development		
Acceptance Criteria: -The website should implement a data logging mechanism that captures relevant information about user and admin activities. -The logged data should include details such as user login/logout events, admin data modifications, and user location retrievals. -The logged data should include timestamps, user or admin identifiers, and specific actions performed. -The system should store the logged data securely to prevent unauthorized access or tampering. -The website should provide an audit trail interface where administrators can view and search the logged data. -The audit trail interface should allow administrators to filter and sort the logged data based on specific criteria. -The system should have appropriate security measures in place to protect the logged data from unauthorized access. -Error handling should be implemented to address any issues that may occur during the data logging and audit trail processes.		

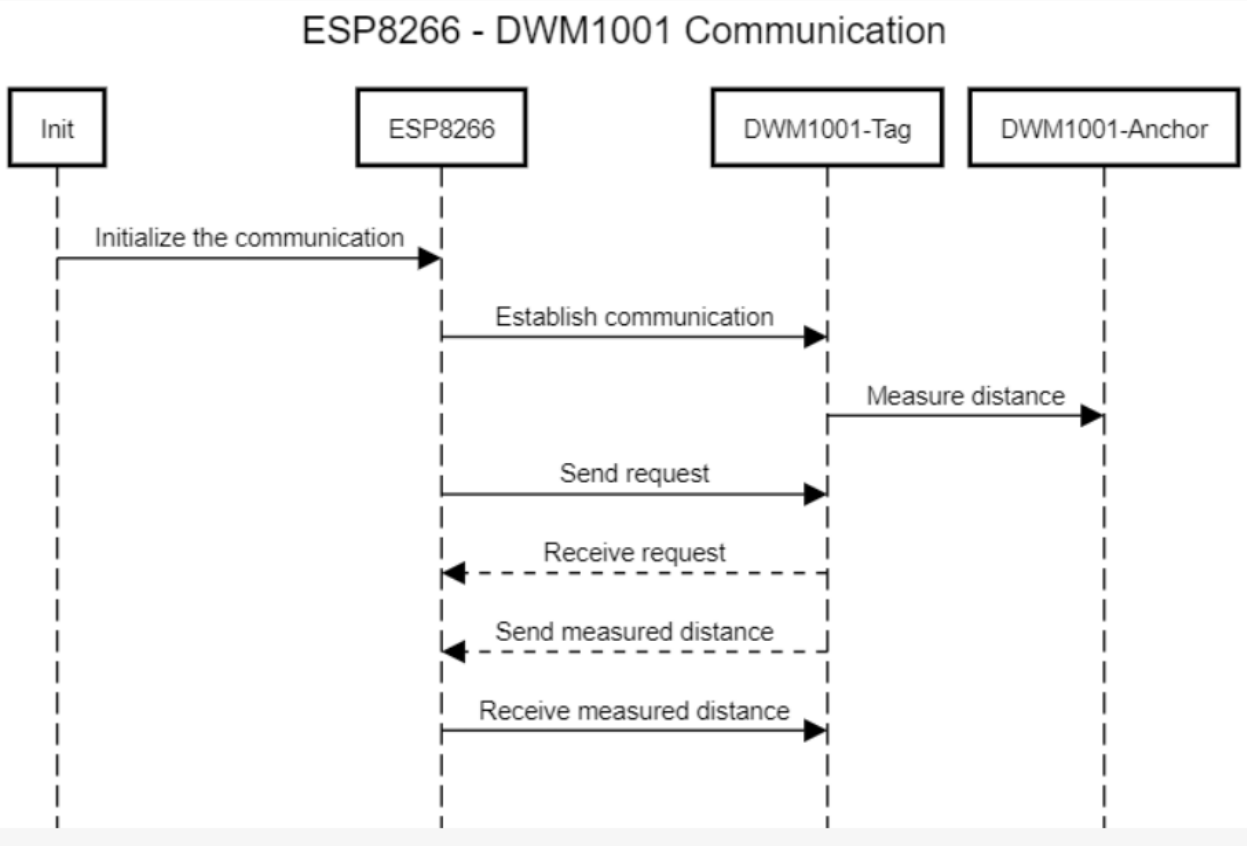
14. Use Case Diagram

Users need to authenticate as tags to get their location data and distance to the chosen anchor or their distance to the point of interest.

Admin needs to authenticate as admin to retrieve all tags and anchors data and make required adjustments.



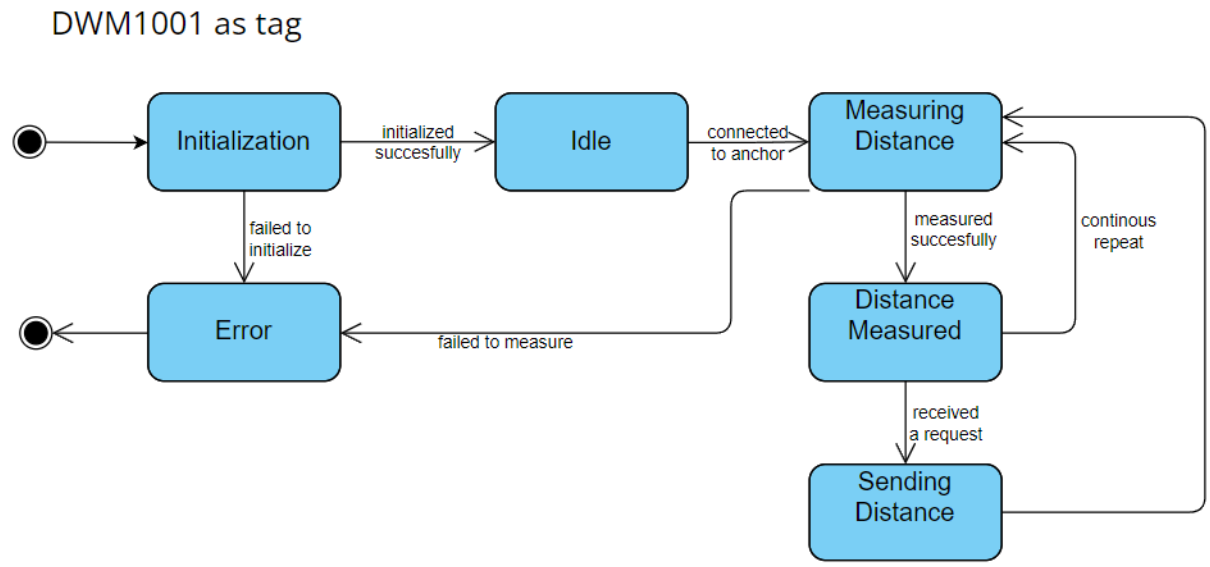
15. Sequence Diagram



The most important and the most demanding part of the project was to establish communication between ESP8266 and DWM1001. The sequence diagram of this transmission illustrates the continuous measurement process where the DWM1001 tag continuously measures the distance and sends the measured distance to the ESP8266 module.

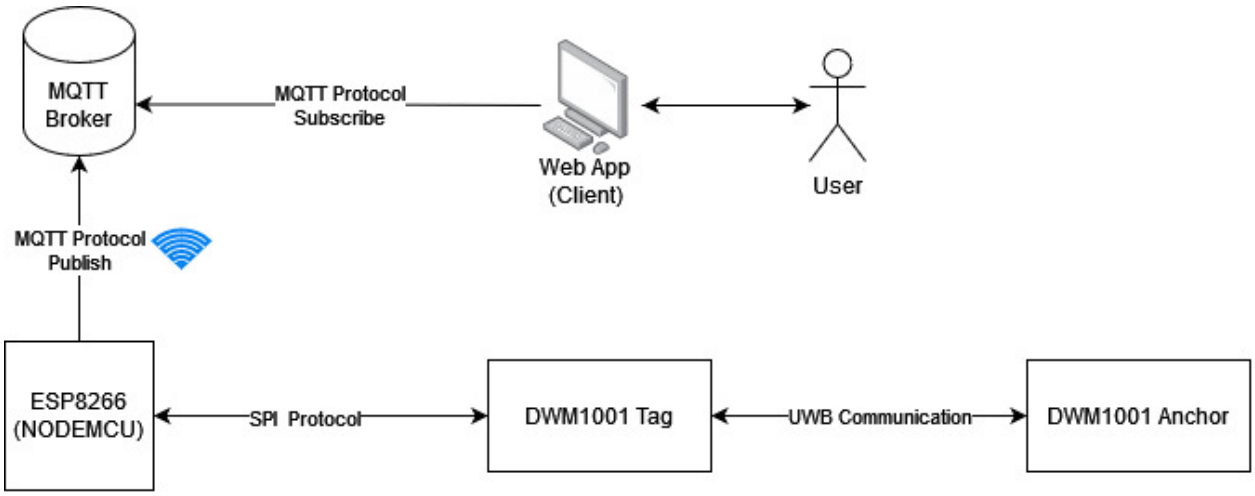
16. State Diagram

DWM1001 tag builds the foundation of the project. Its state diagram highlights the cyclic nature of the DWM1001 tag's behavior, continuously measuring distances and providing the data to the ESP8266 module. It emphasizes the sequential flow of states and indicates that the tag is primarily focused on measuring and sharing distance information.



17. System Architecture

17.1 System Architecture Design



The system architecture for the project consists of several components that work together to achieve the desired functionality. The key components include the DWM1001 tag, ESP8266 module, MQTT client, MQTT broker, and the application layer.

The DWM1001 tag serves as the source of distance measurement, utilizing its built-in capabilities to measure the distance to the DWM1001 anchor. The measured distance data is then sent to the ESP8266 module, which acts as a communication bridge between the DWM1001 tag and the MQTT client.

The MQTT client establishes a connection with the MQTT broker, which serves as a centralized messaging system. The client publishes the measured distance data to the broker, and it can also

receive requests or messages from other subscribers. The application layer coordinates the overall flow of data and control, orchestrating the interactions between the components.

17.2 System Architecture Specifications

Our project involves communicating with the DWM1001 tag by using ESP8266 to retrieve the distance to the DWM1001 anchor and processing this data over MQTT. The most suitable architecture for this scenario is the "Client/Server" architecture commonly used in distributed systems.

In this architecture, the DWM1001 tag is considered as the client, while the ESP8266 module and MQTT broker are considered as the server. This choice can be made for the following reasons:

The Client/Server model reflects the fundamental roles of the DWM1001 tag and the ESP8266 module. The DWM1001 tag provides the data by performing distance measurement (client), while the ESP8266 module receives, processes, and publishes this data to the MQTT broker (server). Communication between the DWM1001 tag and ESP8266 is established using the SPI protocol, where the DWM1001 tag acts as the SPI slave, and the ESP8266 acts as the SPI master.

This architecture clearly defines the data flow and responsibilities in the project. The DWM1001 tag performs distance measurement and sends the measurement results to the ESP8266 module. The ESP8266 module publishes the received data over MQTT. This way, the responsibilities of each component become clear, and a more easily understandable structure is achieved.

The Client/Server architecture is a reliable and scalable approach commonly used in distributed systems. This can facilitate scalability or integration of different components in later stages of our project. With the use of MQTT, message-based communication is established.

17.3 Data Structures

For the data structures, we've separated the message packets that we obtained from the DWM1001 tag device with SPI protocol. The data packages are in TLV format and they contain fields such as error code, tag position x, y, z, number of distances measured, distance address, distance, distance measurement quality, number of anchor positions, anchor position x, y, z. Also the TLV format contains the type codes and the lengths of all these data. Since these values all have different data types such as int32 or int16 etc, we've kept them all in a class called Distance. This way we were able to digest the information and make it ready to send to the MQTT Broker.

17.4 Interface Design

The interface design encompasses both the external interactions and the user interface. Externally, the DWM1001 tag interfaces with the ESP8266 module through the communication protocol, SPI, to exchange distance measurement data. The ESP8266 module interfaces with the MQTT client using MQTT protocols to publish and subscribe to data. The user interface is

designed as a web-based dashboard that allows users to visualize the distance data, configure settings, or interact with the system.

17.5 Performance Evaluation

The report focused on two key metrics: accuracy and speed. To evaluate accuracy, the status of the DWM1001 tag was monitored to ensure it was ready to provide distance/location data to the ESP8266 module. Additionally, the quality of distance data was recorded to facilitate the assessment of measurement accuracy. By enhancing accuracy, the stability of the system was improved, enabling subsequent optimization for speed.

7.