BIA Business and Information Systems Architecture
MGMT-6134-(31)-25F Capstone Project

HEARTLINK: Heart rate Tracking and Analyst

Milestone 1

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1. Project Charter

1.1. Introduction

This project presents the design and implementation of an Internet of Things (IoT) based health monitoring device that can measure and analyze a user's vital signs in real time. The system integrates a MAX30102 pulse oximeter and heart rate sensor with an ESP32 board, which transmits the collected physiological data to a cloud server.

On the cloud side, the data is processed and analyzed using AI-based algorithms to detect patterns related to heart rate variability (HRV) and potential health anomalies. The analyzed results are then visualized through a web-based user interface, providing users with intuitive charts and insights into their cardiovascular health.

1.2 Scope of Work

1.2.1 In Scope

In this section we will detail the specific tasks and strategies that we will employ:

Core Requirements

1. **Hardware Integration:**
   - Implementation of the MAX30102 sensor for heart rate and pulse oximetry measurements.
   - Use of an ESP32 development board for data acquisition, processing, and wireless transmission.
   - Basic prototype assembly using breadboard, jumper wires, and USB power supply.
2. **Data Transmission:**
   - Establishing Wi-Fi connectivity between ESP32 and the cloud server.
   - Sending sensor data in real time using lightweight communication protocols.
3. **Cloud Infrastructure:**
   - Cloud-based data storage and preprocessing of raw sensor signals.
4. **Software and Visualization:**
   - Development of a web-based dashboard for displaying real-time heart rate, HRV trends, and analytical results.
   - Ensure the admin portal is user-friendly and provides efficient content management capabilities.
5. **Testing and Validation:**
   - Verification of sensor accuracy under normal conditions.
   - Validation of system functionality (data flow from sensor → ESP32 → cloud → web UI).

Enhanced Functionality

1. **Implement AI-based analysis of HRV data to provide basic health insights.**
2. **Store historical data in the cloud for trend analysis.**
3. **Add a dashboard with charts.**

Optional Extensions

1. **Provide sleep detection insights based on HR/HRV patterns.**

2. **Add user accounts for personalized tracking.**
3. **Provide blood oxygen (SpO_2) detection using MAX30102's red/IR light sensors**

Stretch Goals

1. **Deploy a machine learning model in the cloud for advanced anomaly detection.**

1.2.2 Out of Scope

It is also essential to clarify what lies outside the scope of this project. Although the goal is to deliver a well-rounded solution, some activities are beyond the boundaries of this work. The following items are therefore excluded from the project:

- **Clinical diagnosis or medical certification of diseases.**
- **Battery-powered wearable hardware design.**
- **Integration of multiple biosensors beyond the MAX30102.**
- **Mobile application development (the system focuses on web-based visualization).**
- **Large-scale deployment or commercial productization of the system.**

1.3 Deliverables

We have outlined the specific deliverables that this project will produce. Each deliverable is aligned with the objectives defined in the scope of work and serves as a tangible outcome that reflects the project's progress and success.

Core Requirements

1. **ESP32 + MAX30102 hardware setup with proper wiring and configuration**
2. **Firmware code for ESP32 to collect heart rate and HRV data**
3. **Cloud integration for real-time data storage**
4. **Web-based dashboard for real-time heart rate visualization**
5. **Documentation (system design, user guide, source code with comments)**

Enhanced Functionality

1. **AI-based HRV analysis module providing stress/fatigue indicators**
2. **Data logging and history tracking with cloud database integration**
3. **Interactive dashboard with charts and trend visualizations**
4. **Basic data security (encrypted communication, user authentication)**

Optional Extensions

1. **Sleep detection insights from HR/HRV data**
2. **SpO_2 (blood oxygen) detection using MAX30102**
3. **Multi-user account support for personalized tracking**

Stretch Goals

1. **Cloud-based ML model for advanced anomaly detection**

1.4 Key Stakeholders

This project relies on the collaboration and support of multiple stakeholders. Each contributes unique expertise and resources that are essential to achieving the project's objectives. The primary stakeholders include:

1. **End Users (General Users / Students / Volunteers)**:
   - Individuals who will test and interact with the prototype device.
   - Provide feedback on usability, comfort, and clarity of health insights.

2. **Cloud Service Providers**:
   - Provide infrastructure for real-time data storage, processing, and availability.
   - Ensure scalability and reliability of the backend system.

3. **Future Investors / Industry Partners (Potential Stakeholders)**:
   - Could be interested in extending the system for commercialization or further research.
   - Evaluate the feasibility of scaling the project into a practical product.

4. **Mentors**:
   - **Vinnie Moraes**:
     Provides guidance, strategic advice, and oversight to ensure the project meets academic and professional standards.

5. **Project Team**:
   1. **Ivan Guan (Project Manager/Embedded Systems Developer)**:
      - Leads the project, manages timelines, and coordinates tasks.
      - Designs and programs the ESP32 with the MAX30102 sensor to ensure accurate data collection and reliable device performance.
   2. **Nguyen Hong Thien Phuc Dinh (Data Engineer / AI Developer)**:
      - Handles cloud integration and data pipelines.
      - Develops AI/HRV analysis modules to interpret health data and generate meaningful insights for end-users.
   3. **Gbubemi Diden (UI/UX Designer/Frontend Developer)**:
      - Designs and builds the web dashboard.
      - Focuses on creating a responsive, user-friendly interface.

1.5 Team Roles

Each member of our team has both a primary and secondary role. This structure ensures that responsibility and accountability are effectively shared. The primary role is the main focus of each team member, while the secondary role serves as a supportive function, providing backup and assistance where necessary.

Role	Responsibilities	Primary	Secondary
Project Manager	Lead the project, manage tasks and timelines	Ivan Guan	Nguyen Hong Thien Phuc Dinh
Data Engineer / AI Developer	Set up cloud connectivity, manage data pipelines, implement HRV/AI analysis	Nguyen Hong Thien Phuc Dinh	Ivan Guan
UI/UX Designer / Frontend Developer	Design and build the web dashboard, ensure user-friendly interface for data visualization	Gbubemi Diden	Nguyen Hong Thien Phuc Dinh
Embedded Systems Developer	Develop firmware for ESP32 and integrate MAX30102 sensor	Ivan Guan	
Quality Assurance / Tester	Test system accuracy, validate data, ensure stable performance and bug-free user experience	Nguyen Hong Thien Phuc Dinh	Gbubemi Diden
End Users (Test Participants)	Interact with the device and dashboard, provide usability and feedback	Ivan Guan, Nguyen Hong Thien Phuc Dinh, Gbubemi Diden	

Table 1: Roles and Responsibilities

1.6 Plan with Event Table

This project is structured around four milestones, running from the start of the term (Sep 3, 2025) through its completion (December 5, 2025). In our plan, milestones differ slightly from each phase of our project, but completing the project phase ensures that the requirements for achieving the milestones are met simultaneously.

Event	Description	Start date	Due date	Status	Priority
Milestone 1	Planning & Requirements	2025-09-03	2025-09-29	Completed	Highest
Milestone 2 & 3	System Design	2025-09-30	2025-10-10	Not Started	High
Milestone 4	Development	2025-10-09	2025-10-31	Not Started	Medium
Milestone 4	Testing & Validation	2025-10-31	2025-11-19	Not Started	Low
Final	Finalization & Reporting	2025-11-19	2025-12-05	Not Started	Lowest

Table 2: Plan with Events

2. Problem Statement

In today's fast-paced world, the risk of heart-related issues is increasing due to stress, unhealthy lifestyles, and pre-existing health conditions. Consequently, individuals are becoming more conscious of their cardiovascular health and the need for regular monitoring.

This project aims to address this problem by developing a low-cost, IoT-based health monitoring system using the MAX30102 sensor and ESP32 microcontroller. The system will measure heart rate and blood oxygen levels, transmit the data to a cloud platform, and display it through a user-friendly web dashboard, enabling users to monitor their vital signs in real time and gain insights into their cardiovascular health.

3. Requirements Gathering

The requirement's gathering process is a critical step in any project, as it defines what the system is expected to achieve. This phase can be divided into three main categories: **Functional Requirements**, which specify how the system should operate; **Non-Functional Requirements**, which define the performance and quality attributes of the system; and **Assumptions, Constraints, and Acceptance Criteria**, which establish project boundaries, implementation standards, and the conditions for project success.

3.1 Functional Requirements

1. **Sensor Data Collection**
   - The system must measure **heart rate (BPM)** using the MAX30102 sensor.
   - The system may measure blood oxygen level (SpO_2) using the MAX30102 sensor.

2. **Data Processing and Transmission**
   - The ESP32 must process raw signals from the MAX30102 into usable metrics.
   - The ESP32 must transmit processed data to a cloud server or web application via Wi-Fi or Bluetooth.

3. **Data Storage**
   - The system must store collected data in a cloud database for future reference and trend analysis.

4. **System Controls**
   - Users may be able to start and stop monitoring via the web interface.

5. **Prototype Testing & Validation**
   - The system must be tested with real human readings to verify accuracy.
   - The prototype must undergo connectivity testing to ensure reliable Wi-Fi or Bluetooth transmission.

3.2 Non-Functional Requirements

1. **Performance**
   - The system must capture and process heart rate (and SpO_2) data in real time with a maximum latency of ≤ 2 seconds between sensor reading and dashboard display.

2. **Reliability & Availability**
   - The system must provide at least 95% uptime during testing and demonstrations.

3. **Scalability**
   - The cloud platform must allow for at least 5 simultaneous users viewing the dashboard without performance degradation.
   - The database must be capable of storing at least 1 month of continuous data per user.

4. **Usability**
   - The web interface must be friendly and accessible on standard browsers.
   - The dashboard must use clear graphs and color indicators (e.g., green for normal, red for abnormal readings) to ensure easy interpretation.

5. **Maintainability and Extensibility**
   - The system must be modular, allowing easy migration to another cloud provider without major code changes.
   - Documentation must be provided for hardware setup, software code, and cloud configuration to support future improvements.

6. **Security & Privacy**
   - Data transmission between ESP32 and cloud must be encrypted using HTTPS or equivalent.
   - User data must be accessible only with secure login credentials.

7. **Compliance (Ethical & Safety)**
   - The system must include a disclaimer that it is for educational and demonstration purposes only, not for clinical diagnosis.
   - The device must operate within safe limits of LED light exposure defined by the MAX30102 datasheet.

3.3 Assumptions, Constraints, and Acceptance Criteria

This section outlines the key assumptions, constraints, and acceptance criteria for our project. The assumptions lay out the fundamental conditions we believe to be true, which influence the project's scope and execution. The constraints are the limiting factors that could impact on the progress and quality of the project. We have also detailed the acceptance criteria, which are the conditions that the project must meet for successful completion. Our goal is to ensure a high-quality end-product that meets our client's needs and expectations.

3.3.1 Assumptions

1. **User Environment:**
   - Users will remain relatively still during measurements to minimize motion artifacts.
   - The finger placement on the MAX30102 sensor will be correct and consistent.

2. **Hardware Availability:**
   - The ESP32 board and MAX30102 sensor module are available and functional throughout the project.
   - A stable power source (USB or battery) is available for continuous operation.

3. **Connectivity:**

- A stable Wi-Fi network is available for data transmission from ESP32 to the cloud.
- Internet access will be available for cloud database and dashboard hosting

4. **Software & Tools:**
   - Open-source libraries for ESP32–MAX30102 communication and data processing are available and reliable.
   - Cloud services will be accessible within free or academic tiers.

5. **Project Scope & Constraints:**
   - The project will focus on **heart rate (and blood oxygen) only**; no other medical parameters will be included.
   - The system will be used strictly for **educational and demonstration purposes**, not for clinical use.

3.3.2 Constraints

1. **Hardware Limitations:**
   - The accuracy of heart rate and SpO_2 readings is limited by the MAX30102 hardware capabilities and may not match medical-grade devices.

2. **Budget:**
   - The project budget is limited to **low-cost components (< $100 CAD)**, restricting the choice of sensors, cloud services, and development tools.

3. **Technical Constraints:**
   - The ESP32 has limited processing power and memory, restricting the complexity of onboard data analysis.
   - Data analysis beyond basic processing (e.g., advanced AI/ML models) must be handled in the **cloud**, not on the ESP32.

4. **Data & Connectivity:**
   - Reliable Wi-Fi connectivity is required; performance may degrade in unstable network environments.

5. **Ethical & Safety Constraints**
   - The system must clearly state it is for **educational/demonstration purposes only** and not intended for clinical diagnosis or treatment.
   - Testing will be conducted on **healthy volunteers only**, not on patients with medical conditions.

3.3.3 Acceptance Criteria

Core Requirements:

Criterion	Description	Acceptance Standard	Verification Method
Sensor Data Collection	ESP32 should acquire heart rate data from MAX30102.	Sensor provides stable readings with accuracy ±5 bpm.	Compare against a commercial HR monitor in tests.
Data Transmission	ESP32 should send data to the cloud server.	≥95% of packets reach the server without corruption.	Server log review and packet loss monitoring.
Data Visualization	Dashboard displays live heart rate data.	Data visible on frontend within 3s of capture.	Functional demo and timestamp verification.

Table 3: Acceptance Criteria – Core Requirements

Enhanced Functionality:

Criterion	Description	Acceptance Standard	Verification Method
AI Analysis	System analyzes heart rate patterns and provides feedback.	Correctly identifies normal/irregular patterns in 90% of test cases.	Test with simulated and real datasets.
User Dashboard Experience	Dashboard should be user-friendly and clear.	Users navigate data without prior training.	User surveys and usability testing.

Table 3: Acceptance Criteria – Enhanced Functionality

Optional Extensions:

Criterion	Description	Acceptance Standard	Verification Method
Blood Oxygen Detection	Provide SpO_2 measurement via MAX30102.	Readings within ±2% compared to a reference oximeter.	Testing with volunteers against medical oximeter.
Historical Data Storage	System should log past data for trend viewing.	At least 7 days of history retrievable on dashboard.	Database query test and user dashboard check.

Table 5: Acceptance Criteria – Optional Extensions

Stretch Goals**:**

Criterion	Description	Acceptance Standard	Verification Method
Sleep Monitoring	Estimate user's sleep/wake states from HR data.	≥80% accuracy when compared to self-reported sleep logs.	User trial with diary comparison.

Table 6: Acceptance Criteria – Stretch Goals

4. Relevance and Significance.

- Continuous monitoring of heart rate and blood oxygen levels is essential for maintaining cardiovascular health and preventing serious conditions.
- This project provides a low-cost, portable, and easy-to-use solution for real-time health monitoring using the MAX30102 sensor and ESP32.
- The system transmits data to the cloud and displays it via a user-friendly web dashboard, enabling users to track their health outside clinical settings.
- Empowers users to be more aware of their cardiovascular conditions and take proactive measures for their well-being.
- Serves as an educational platform, giving students practical experience in embedded systems, IoT, and data visualization.
- Lays a foundation for future research and development in digital health, wearable technology, and AI-driven health insights.

5. Resources

To successfully complete our projects, we utilize a variety of resources. These resources range from technological tools used for development, design, testing, deployment, and security, to human resources such as our project team, professors, and key stakeholders. Below is a detailed breakdown of our resources:

5.1 Technological Resources

1. ***Tools for development:***
   - **IDE / Code Editors: A**rduino IDE, PlatformIO, or Visual Studio Code for ESP32 programming.
   - **Version Control:** GitHub for source code management, collaboration, and version tracking.
   - **Programming Languages:** C/C++ for ESP32 firmware, Python or JavaScript for cloud data processing and dashboard development.

- **Cloud Database Services:** Firebase, AWS, or Google Cloud for storing and retrieving health data.

2. ***Tools for Design:***
   - **UI/UX Design:** Figma or Adobe XD for designing the dashboard and user interface.
   - **Visualization Tools:** Chart.js, D3.js, or Plotly for displaying real-time graphs of heart rate and SpO_2.

3. ***Tools for testing:***
   - **Unit Testing:** Arduino Unit or custom Python scripts to test sensor data accuracy and processing.
   - **Performance Testing:** Measure latency, connectivity, and data transmission reliability between ESP32 and cloud dashboard.

4. ***Tools for Deployment and Hosting:***
   - **Web Hosting:** Firebase Hosting or AWS Amplify for deploying the web dashboard.

5. ***Security Tools:***
   - **Data Encryption:** HTTPS/TLS for secure transmission of sensor data to the cloud.
   - **Authentication:** Firebase Authentication or similar for secure user login.

6. ***Tools for Project Managing and Collaborating:***
   - **Project Management:** Microsoft Project or Jira to track tasks, milestones, and deadlines.
   - **Communication & Collaboration:** Microsoft Teams, Google Meet, or Zoom for team meetings.
   - **Documentation:** Google Docs, Notion, or Microsoft Office Suite for maintaining project documentation.

5.2 Human Resources

- **Project Team:** Embedded systems developer (ESP32 programming), cloud/data engineer (AI/HRV processing), UI/UX designer (dashboard), and tester.
- **Professors:** Professors providing guidance, feedback, and technical advice.
- **Test Users:** End users for usability testing and feedback.

6. Gantt Chart and Critical Path

The figures below shows our monthly version of the Gantt Chart and the Critical Path of the project.

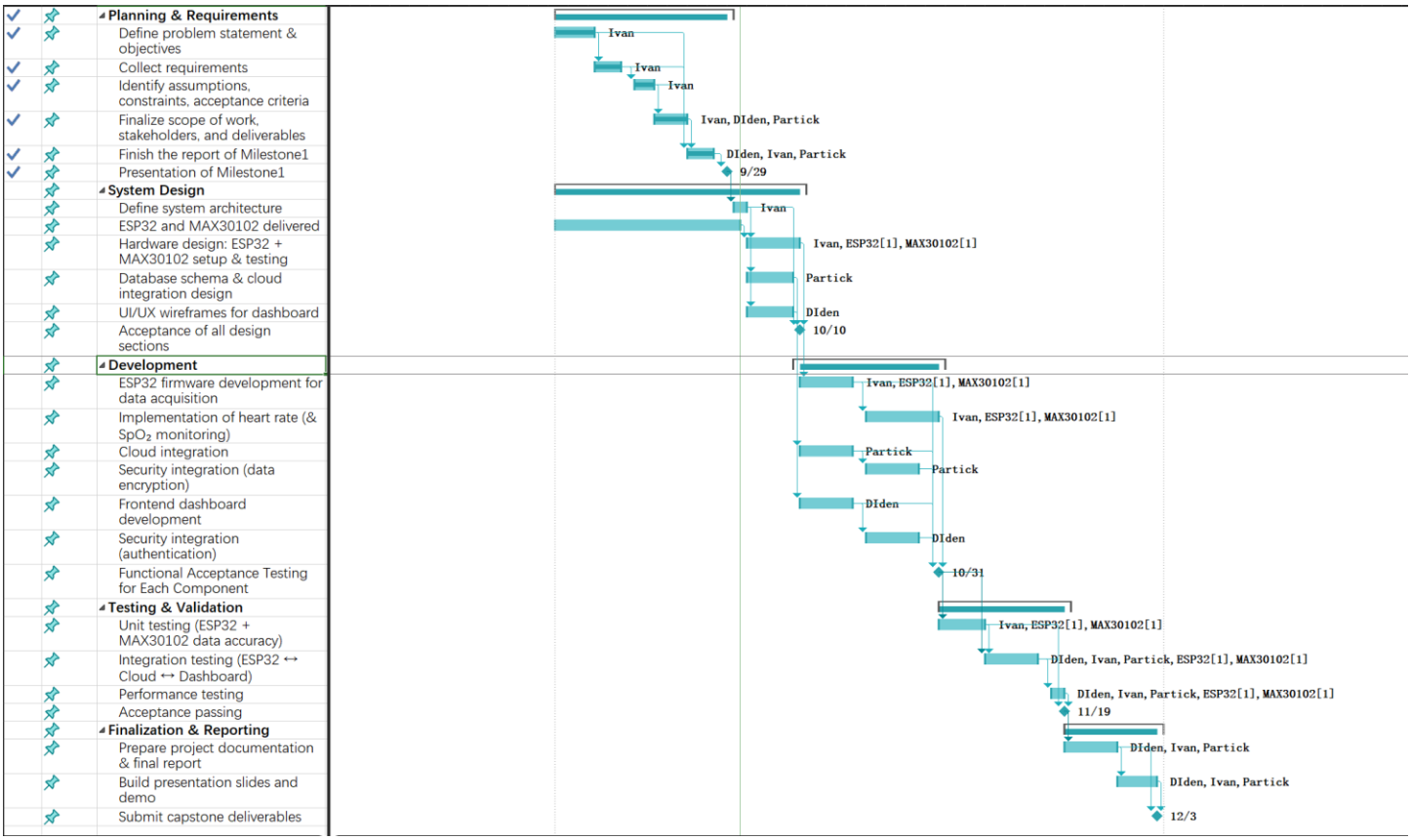

Figure 1: Gantt Chart View

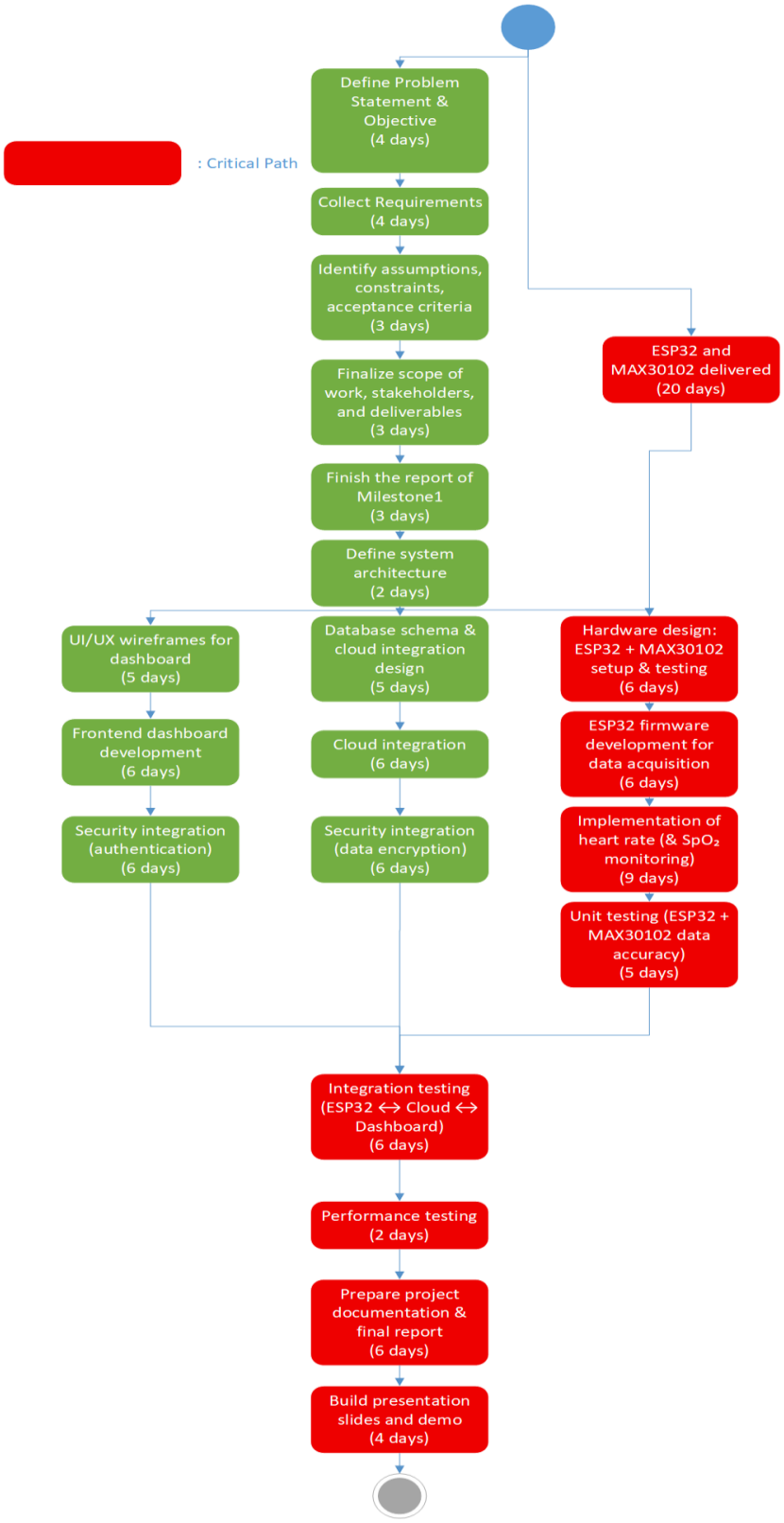

Figure 2: Critical Path View

7. References

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