HIGH LEVEL DESIGN DOCUMENT

Smart Classroom Solutions

UE18CS390A – Capstone Project Phase – 1

Submitted by:

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Note:

Section – 1 & Section 2	**Common for Product Based and Research Projects**
Section 3 to Section 11	**High-Level Design for Product Based Projects.**
Section 12	**High-Level Design for Research Projects.**
Appendix	**Provide details appropriately**

1. Introduction

The High-Level Design Document highlights the concept and necessary detail for implementing an IoT-based enhanced learning environment. A combination of use case, activity and sequence diagrams provides a detailed idea behind the product. These diagrams show the relationship between the users and the admins and the cloud platform(system) and the interaction between them. These diagrams will help in the smooth transition into the implementation phase of our project.

2. Current System

Attendance plays a pivotal role in determining academic performance of children and youth in schools and colleges. The regularity of attendance shows that the students are less likely to engage in delinquent or destructive behavior. Chronic absence increases the risk of school failure and early dropout.

Manual maintenance of attendance is inefficient due to the following reasons:

- It takes away a lot of lecture hours.
- Prone to proxies or impersonations.

The existing solutions to tackle the above problems include automatic face detection and RFID scanners.

- Developed in 2001 by Paul Viola and Michael Jones, the **Viola-Jones algorithm** is an object-recognition framework that allows the detection of image features in real-time.

Viola-Jones outlines a box and searches for a face within the box. However, there is room for improvement since these systems sometimes fail to recognize every face student present in the classroom. It also poses a lag of a few seconds as the system needs to detect a face. The algorithm used also gives best results in the frontal view of the face and might fail in other cases.

- **Radio-Frequency IDentification (RFID)** offers solutions to solve the above problem because of its strong anti-interference capability and non-intrusiveness. However, this too can be easily by passed as the RFID tags are easy to transport and hence reliability becomes a matter of concern.

Electricity consumption is one of the biggest concerns affecting the world community. Current scenario insists towards highly efficient and effective usage of any form of power in educational institutions like colleges and universities where we use power for our teaching in classroom or labs. Most of us i.e., students and faculty members are habituated towards leaving the classroom without switching the lights and fans, which leads to unnecessary consumption of energy for organization and paying huge amount of bill from their budget.

The system developed will control lighting in particular area of classroom based on the presence of human using relay control compared to the one placed in ceiling which would switch on or off based on presence of human in room irrespective of position.[4] This paper uses **PIR sensors and an Arduino UNO** to implement as automatic system of lights and fans. However, due to the low computational power of an UNO, the cost incurred as a result of the number of microcontrollers required is high. In addition, mobile application given to the user's towards switching appliances on or off via Bluetooth too.

3. Design Considerations

3.1. Design Goals

- **Attendance:**

1. Attendance can be taken electronically by means of a biometric optical fingerprint scanner.
2. Security and integrity can be ensured by making the biometric module portable and modular - a small phone sized module carried by the teachers.
3. The teacher can pass around/have each of the students scan their prints and register their attendance with no manual intervention.

- **Electricity Optimization:**

1. Spatial sensors placed at the edges of classrooms will notify the system of movement and activity in the room.
2. Edge computed algorithms ensure that the lights and fans are turned on only at specific portions of the room incase of a large classroom/hallway.
3. In case of manual fans, temperature monitors are used to add a level of cost-effective automation.

- We are trying to build a fool-proof system in this project considering the ways students can bypass these systems.
- Real-time implementation of the project that is independent of wiring system of the institutions.

3.2. Architecture Choices

Multiple alternate ways to take attendance were considered however, none of them proved to be as reliable and as viable as our solution as most of them proved to be too unwieldy or posed a security concern or straight up could be tampered with:

- *Attendance Logging via Face Detection:*
  - Attendance to be logged in via a camera that would use algorithms that would detect faces.
  - Pros:
    - Simple and easy for students.
    - Seamless attendance by just showing your face in the camera as you walk in.
    - Zero Time wasted as attendance is taken as students walk in.
  - Cons:
    - Very unwieldy, may not work accurately.
    - Lot of variables deciding its effectiveness such as lighting etc.
    - Twins and lookalikes may pose an issue.
    - Actual logging may take time as algorithms take time to recognize faces.

- *Attendance Logging via Single fingerprint scanner:*
  - Attendance to be logged in via a single fingerprint scanner placed at the entrance of the classroom.
  - Pros:
    - Makes the teacher's life easier as students can manage taking their attendance themselves.
    - Less expensive as fingerprint scanner to be considered doesn't need to be portable or high tech.
    - No inaccuracies as fingerprints are an extremely reliable means of identification.

- Cons:
  - Easier to tamper: Students can just log in to the attendance and walk out of the classroom, hence registering a false attendance.
  - No overseeing by the teacher as she has no control over classroom-based sensors.

Eventually, our system was devised which provided the maximum balance between functionality and cons:

- Attendance taken via individual scanners held by teachers:
  - Pros:
    - Teachers have full control over when they can take attendance as the device is constantly with them.
    - Students cannot fake attendance as the teacher decides when the attendance can be taken, once everyone has been settled in the class and the door has been closed.
    - Students can't log in attendance and walk out of the class as the device would be passed along in the classroom.
    - Teachers can give explicit attendance under their own discretion such as when a student walks in late etc.
  - Cons:
    - Expensive: Involves the purchase of high-end scanners that can be condensed into portable modules for easy handling.
    - Involves some time wastage as students need to log in attendance one by one once everyone has settled in.
    - The device may be prone to damage if it has been extensively being passed on.

3.3. Constraints, Assumptions and Dependencies

- Availability of Raspberry Pico:

  Raspberry Pico is very new to the market and needs to be tested whether it satisfies all the requirements for the project. As per the documentation, it does seem to satisfy them. As a backup, we would still have Raspberry Pi ready, but the cost would be more if we use Raspberry Pi instead of Raspberry Pico.
- Server systems in the Institutions:

  Our project also highly depends upon how the server system exists at a particular institution. If there is no existing server, it would be very easy to implement. If there exists a server, then we have to check how exactly we will be able to implement our project on it.
- Existing Wiring in Institutions:

  It depends which wiring system exists at the institution because our project would work on almost every existing wiring system unless it's very old.

4. High Level System Design

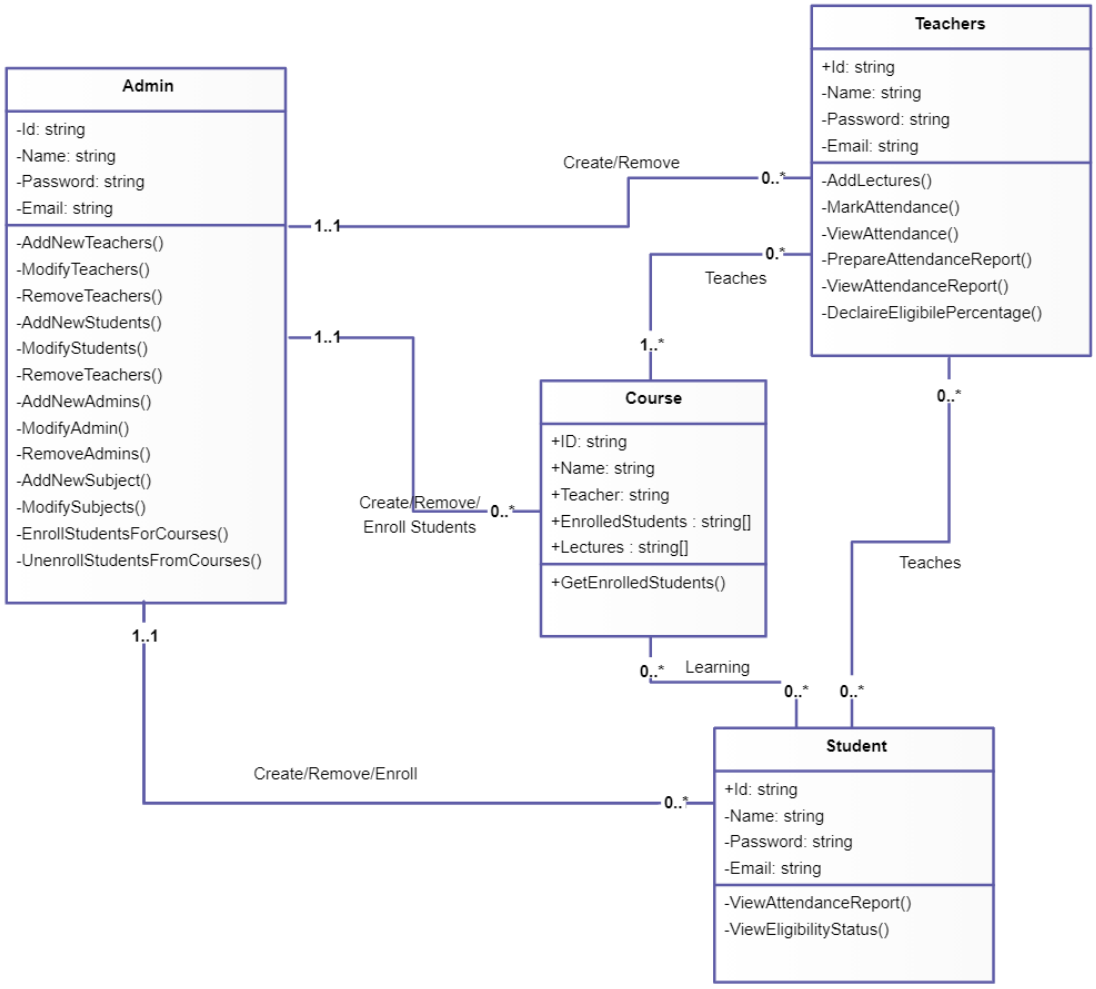
- *Logical User Groups:*
  - Teachers:
    - The teacher is given dashboard permissions to view and manage the attendance and given regular updates as to when the students come to class. The teacher is also given notifications in case of any outliers and can also edit attendance as and when necessary.
  - Students:
    - The students have permissions to only log in the attendance via fingerprint under the teacher's discretion when the teacher so allows it. The student has no further permissions and if he/she wishes to edit her attendance due to any issue/manual logging, they can only approach the teacher and the teacher can do so under her discretion. The student can also control the temperature of the room and its lighting.
  - Administrator:
    - The administrator oversees all the attendance and the database functions. Only the administrator has full access to the database and its core. Every single operation undertaken by the teacher and the student is logged into an audit log. The admin has access to this log and in the event of any emergency/malpractice, the administrator has a clear view of what is happening at all times. He/she also has access to the database and its connections and can undertake any database operations if necessary.

  - *Data Components:*
    - Raw Fingerprint Data:
      - This is the raw fingerprint values which registers every time a student scans his/her fingerprint.
    - Power Consumption Values:
      - These values are logged for database analysis purposes. They are the total power consumption values on an hourly basis per classroom.
    - Current Room temperature:
      - This stat is the current room temperature which will be monitored. It is according to this stat that the appliances such as fans will be modulated.

    - Database connectors:
      - All data and actions taken by the device will be relayed onto the database via database connector which will be running on the microcontroller. Every action including the actions of all users in the user groups will be logged via an audit log.

5. Design Description

5.1. Master Class Diagram

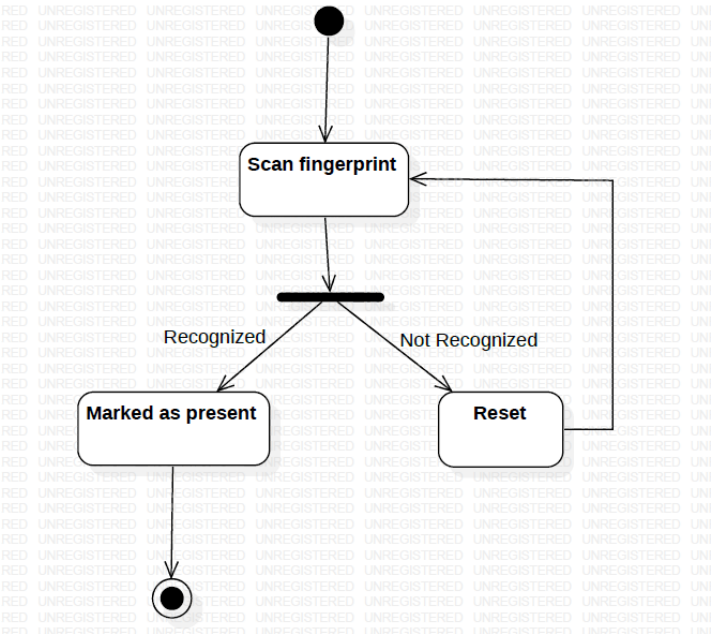


5.2. Reusability Considerations

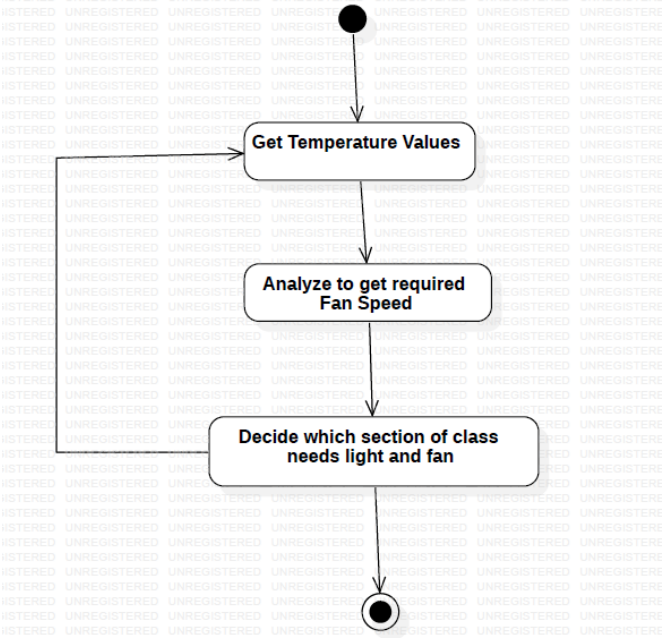
- The assortment IoT sensors installed in the classrooms are durable and need not be replaced often.
- The server installation too is a one-time process. However, the ThingSpeak and Firebase backends need to be paid for on a yearly basis depending on the usage.
- The ML models used for attendance summarization and fan speed detection are reused and some extra layers(mechanism) have been added on top of that. These models are constantly learning from manual user intervention.

6. State Diagrams

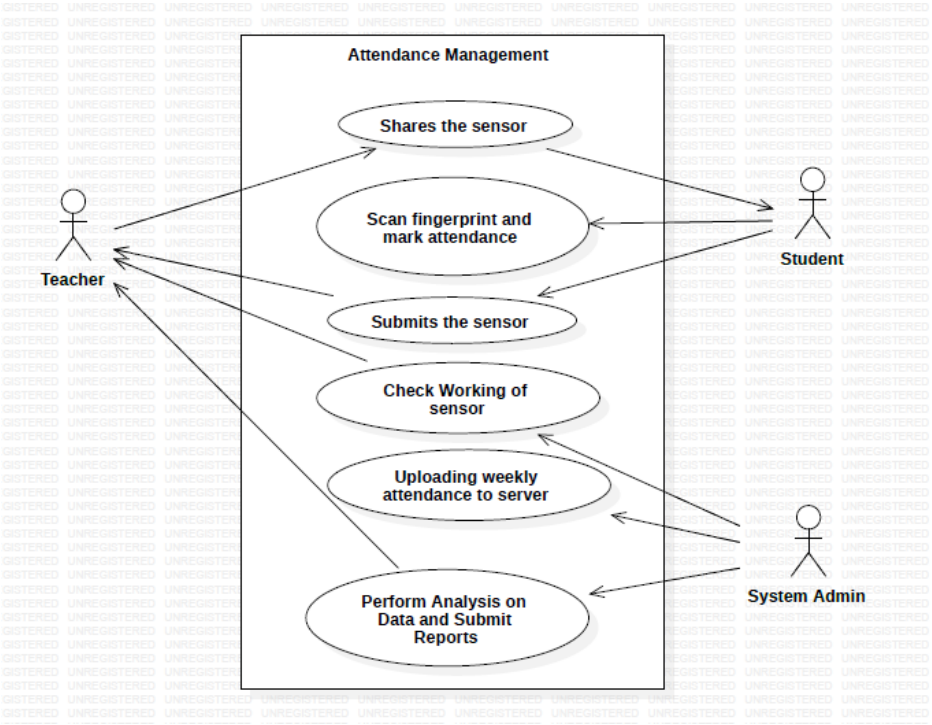
- Attendance:



- Electricity Optimization:



7. User Interface Diagrams



8. Report Layouts

- Not applicable for the project since we use unstructured data in the backend.

9. External Interfaces

User Interfaces

- Dashboard for the teachers to view attendance.
- Interface for the teachers for manually provide attendance if the sensor fails.
- Controls for the teachers to perform analysis on the intake of students on a per subject basis.
- Controls for the system admin to oversee the registration and authentication of each student.

Hardware Requirements

- UART Capacitive Fingerprint Sensor
- Absolute Native Electronics W1209 50~100 digital temperature controller thermostat
- Tolako 5v Relay Module
- PIR Motion Detector Sensor Module HC-SR501
- Microcontroller: Raspberry Pico/ Raspberry Pi
- Transmitter and Receiver for 1km range.

Software Requirements

Wireless Connectivity	1	Wi-Fi Module Specifications: • Model Number: ESP8266 • Color: Black • Form Factor: All-in-One • Item Weight: 60.0 grams
Server	1	• ThingSpeak: Home License • Number of messages: 33 million/year per unit (~90,000/day per unit) • Message update interval limit: Every second • Number of channels: 10 per unit

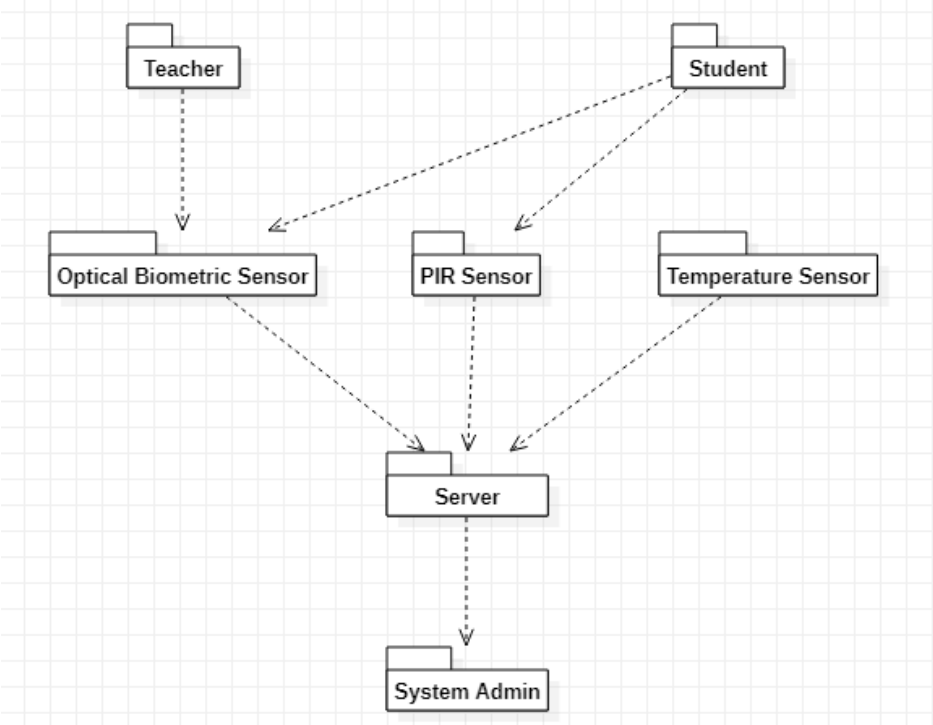
Communication Interfaces

• Wi-Fi: Connectivity of each of the microcontrollers on every floor will be ensured through Wi-Fi.

• Bluetooth: Connectivity of the fingerprint scammer to the microcontroller will be ensured through Bluetooth.

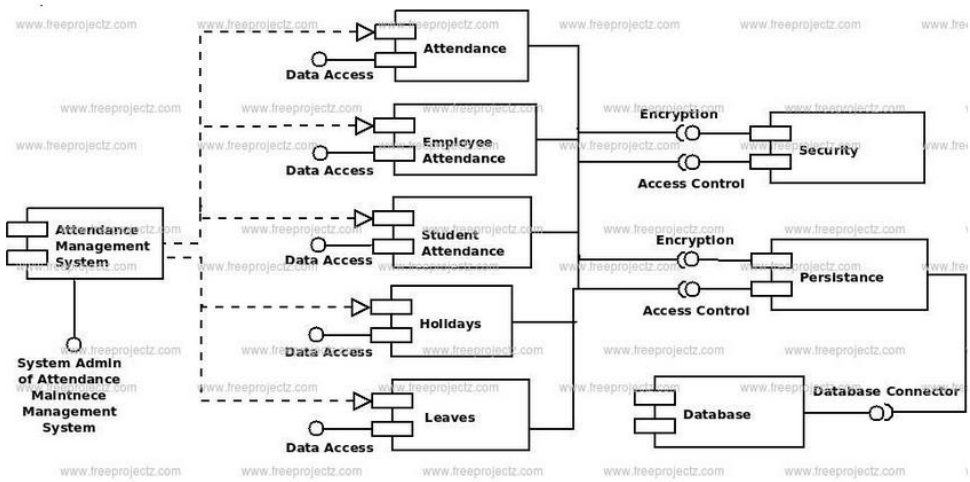
10. Packaging and Deployment Diagram

Packaging Diagram:

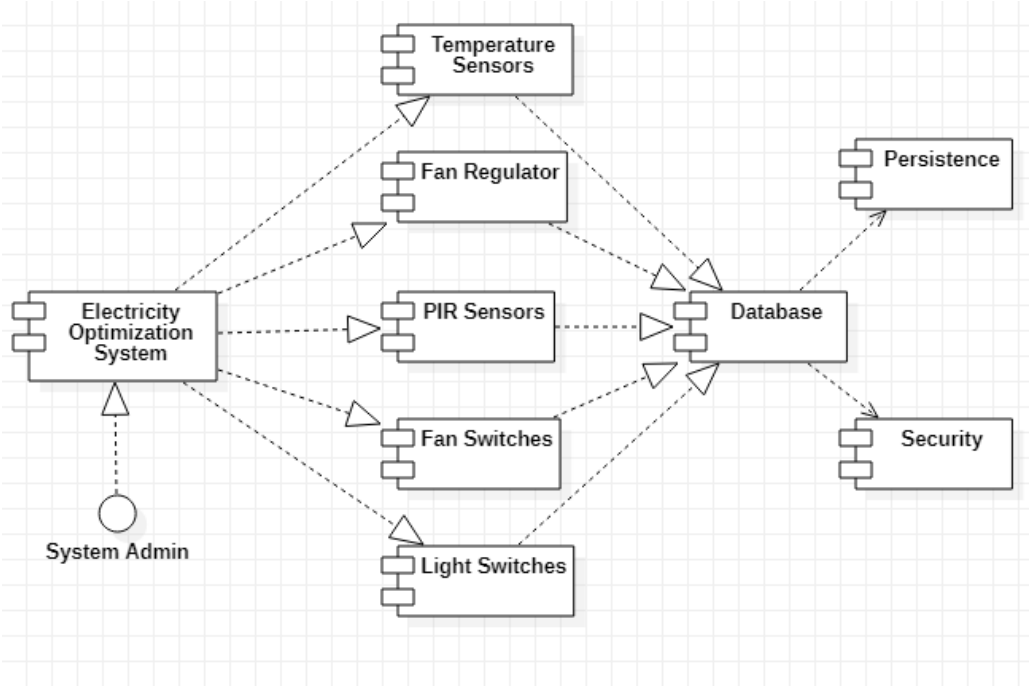


Deployment Diagram:

- Attendance System



- Electricity Optimization



11. Help

A User Manual Page will be provided along with the guidelines and related diagrams for easy installation of our system. It would also contain the maintenance procedure on how to go about using the application and preventing the end user from stalling at any point.

As the admin will be the only point of interaction, a proper documented API documentation will be provided to the administrator. This will be generated using the POSTMAN software.

12. Design Details

12.1. Novelty

- Fool proof solution is important keeping in mind the innovative ways students find to bypass attendance systems.
- Real-time implementation that is independent of the wiring system.

12.2. Innovativeness

- Dashboard for the teachers to view attendance.
- Interface for the teachers for manually provide attendance if the sensor fails.

12.3. Interoperability

- Controls for the teachers to perform analysis on the intake of students on a per subject basis.
- Controls for the system admin to oversee the registration and authentication of each student.

12.4. Performance

- Our product is designed to be extremely versatile, and it doesn't have any specific conditions to work under and no external factors are going to affect the performance of the product.
- The fingerprint scanner is also extremely reliable as it will still be able to take a reading regardless of external factors.
- As for the smart classroom system, the sensors are easily available and are very effective for the use that we are putting them to and are not that easily affected by external factors.

12.5. Security

- Security is not an issue with our product as the device will always be in the possession of the teacher and all the microcontrollers for the electricity saving model will be in the possession of the floor admin.
- The data collected will be stored safely on a server which is only accessible by the system admin.

12.6. Reliability

- The fingerprint scanner is very reliable and will be able to take the readings irrespective of the external factors and conditions.
- The temperature sensors too are not that easily affected to external factors.

12.7. Maintainability

- The fingerprint scanners would be checked regularly.
- The students also can report to the teachers if there is some problem with the fingerprint scanner.
- The temperature sensors can be replaced occasionally and the best way to know that a sensor is not running is when it does not send any data across or it sends irregular data.

12.8. Portability

- The fingerprint scanner is attached with the mic and will be carried by the respective teachers to the classes they visit.

12.9. Reusability

- After implementation, we can extend this project to various other institutions and organizations.

12.10. Application compatibility

- This system is compatible with any organization and institution since it is independent of the wiring system.

Appendix A: Definitions, Acronyms and Abbreviations

- ThingSpeak: Open-source IoT application and API to store and retrieve data from things using the HTTP and MQTT protocol over the Internet or via LAN.
- Capacitive Fingerprint Scanner: uses capacitance to gauge the depth of the finder and collect the fingerprint.
- Relay: A relay is an electrically operated switch. It consists of a set of input terminals for a single or multiple control signals, and a set of operating contact terminals.
- Thermostat: A thermostat is a regulating device component which senses the temperature of a physical system and performs actions so that the system's temperature is maintained near a desired setpoint.
- Microcontroller: A microcontroller is a small computer on a single metal oxide-semiconductor integrated circuit chip.

Appendix B: References

[2] S. Bhattacharya, G. S. Nainala, P. Das and A. Routray, "Smart Attendance Monitoring System (SAMS): A Face Recognition Based Attendance System for Classroom Environment," 2018 IEEE 18th International Conference on Advanced Learning Technologies (ICALT), Mumbai, India, 2018, pp. 358- 360, doi: 10.1109/ICALT.2018.00090.

[4] Suresh S., H. N. S. Anusha, T. Rajath, P. Soundarya and S. V. P. Vudatha, "Automatic lighting and Control System For Classroom," 2016 International Conference on ICT in Business Industry & Government (ICTBIG), Indore, India, 2016, pp. 1-6, doi: 10.1109/ICTBIG.2016.7892666

Appendix C: Record of Change History

#	Date	Document Version No.	Change Description	Reason for Change
1.	**11.04.2021**	**1.0.0**	**First Draft**	**-**
2.				
3.				

Appendix D: Traceability Matrix

Project Requirement Specification Reference Section No. and Name.	DESIGN / HLD Reference Section No. and Name.
2: Literature Survey on Existing System	2: Current System
3.4: General Constraints, Assumptions and Dependencies	3.3: Constraints, Assumptions and Dependencies
5: External Interface Requirements	9: External Interfaces