

INDOOR POSITIONING SYSTEM

A Project Report Phase – II

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering degree in Electronics and
Communication Engineering

by

Jahan S (39130176)



DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
SCHOOL OF ELECTRICAL AND ELECTRONICS

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

**Accredited with Grade "A" by NAAC
JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI – 600 019**

APRIL – 2023



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BONAFIDE CERTIFICATE

This is to certify that this Project Phase-II Report is the bonafide work of **Jahan S (39130176)** who carried out the project entitled “**INDOOR POSITIONING SYSTEM**” under my supervision from November 2023 to April 2023.

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Submitted for Viva voce Examination held on_____.

Internal Examiner

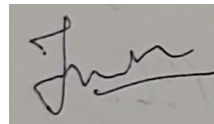
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DECLARATION

I **JAHAN S (39130176)** hereby declare that the Project Report entitled “**INDOOR POSITIONING SYSTEM**” done by me under the guidance of **Dr. T. RAVI**, M.E., Ph.D., Head of the Department, Department of Electronics and Communication Engineering at Sathyabama Institute of Science and Technology is submitted in the partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Electronics and Communication Engineering.

DATE:

PLACE: Chennai

A rectangular box containing a handwritten signature in black ink. The signature appears to be 'Jahan S' with a stylized flourish at the end.

SIGNATURE OF THE CANDIDATE

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I am pleased to acknowledge our sincere thanks to the Board **of Management of SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. We are grateful to them.

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ABSTRACT

The use of unmanned aerial vehicles (UAVs) has rapidly increased in recent years, owing to their enormous potential in both civil and military applications, as well as the decreasing cost of unmanned aerial vehicles (UAV) products. While location detection can be implemented using Global Navigation Satellite System (GNSS) technology in outdoor environments, its accuracy may be insufficient for certain applications. The use of GNSS in indoor environments is limited due to signal attenuation when it crosses walls or due to the absence of a line of sight. This limitation presents an opportunity for the exploration of alternative solutions for positioning indoor UAVs. This project aims to investigate the use of Bluetooth Low Energy (BLE) technology in combination with BLE beacons that can be deployed at specific locations to estimate the drone's location using Received Signal Strength Indication (RSSI) techniques and Trilateration methods. By utilizing this method, the drone can locate its position indoors with greater accuracy, offering potential applications in various fields such as defense, inventory management, airports, and underground locations. As the cost of UAVs and BLE beacons continues to decrease, this technology has the potential to revolutionize the way UAVs are utilized in these industries.

Keywords:

UAV, Internet of Things, BLE, RSSI, Trilateration.

TABLE OF CONTENTS

CHAPTER No.	TITLE	Page No
	Acknowledgement	iii
	Abstract	iv
	List Of Figures	vii
	List of Tables	viii
1	INTRODUCTION	1
	1.1 Indoor Positioning System	2
	1.2 Trends and Futures	3
2	LITERATURE SURVEY	4
	2.1 Interference from the Literature Survey	4
	2.2 Literature Summary	8
	2.3 Problem Definition	9
	2.4 Objectives of the Project	9
3	AIM AND SCOPE OF THE PRESENT INVESTIGATION	10
	3.1 Proposed Methodology - RSSI	10
	3.2 Area of Project and Application	11
	3.3 Triangulation	12
	3.4 Existing Work	14
	3.5 Disadvantage of Existing Work	15
	3.6 Proposed Triangulation using Distance from RSSI	16
4	PROPOSED METHODOLOGY	17
	4.1 Proposed System	17
	4.2 Proposed System Advantages	17
	4.3 Block Diagram of the IPS	18

4.4	Hardware Description	19
4.4.1	<i>ESP</i>	19
4.4.2	<i>ESP 32</i>	20
4.4.3	OLED Display	22
4.5	Software Description	23
4.5.1	Arduino IDE	23
4.5.2	Fusion 360	24
4.5.3	GITHUB	25
4.6	Cost Estimation of the Project	27
5	PROJECT IMPLEMENTATION	28
5.1	Access Point Allocation	28
5.2	Scanner Setup	29
5.3	Node Deployment	29
5.4	Lab Information and Website Hosting	30
6	RESULT AND DISCUSSION	32
6.1	Stimulation Result	32
6.2	Serial Monitor Output	33
6.3	Web Hosting	34
6.4	Proposed Outputs	35
7	CONCLUSION	38
7.1	Conclusion	38
7.2	Future Scope	39
	REFERENCES	40

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE NO.
3.1	Triangulation	13
4.1	Block Diagram of the IPS	18
4.2	EPS32	20
4.3	Pin Diagram	21
4.4	OLED Display	22
4.5	Arduino IDE logo	23
4.6	Fusion 360 logo	25
4.7	GITHUB logo	26
5.1	Three ESP32 Device	28
5.2	Connecting the ESP32 and OLED Display	29
6.1	Finding RSSI on Phone	32
6.2	Output of the serial monitor	33
6.3	Screenshot of Microprocessor and Microcontroller Lab	34
6.4	Screenshot of Electronics Circuits Lab	35
6.5	Screenshot of Microwave and Optical lab	35
6.6	Image of QR code and MPMC Lab name	36
6.7	Image of QR code and Electronics Circuits Lab name	36
6.8	Image of QR code and Microwave and Optical Lab name	37

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
4.3	Cost Estimation	27

CHAPTER – 1

INTRODUCTION

The need for indoor positioning systems has been increasing over the years, driven by the proliferation of wireless technology and the growing demand for location-based services. Wireless indoor positioning systems have proven to be effective in various applications such as asset tracking, airports, museums, inventory management, and many others. These systems have made life easier and more convenient for individuals, allowing them to locate objects, people, and places accurately and quickly.

With the rise of mobile computing and the internet, new opportunities have emerged to create portable applications that can further enhance the capabilities of indoor positioning systems. Mobile phones have become an indispensable part of our daily lives, and researchers have been exploring ways to turn them into specialized communication and navigation tools. Navigation systems are becoming increasingly important, and the demand for indoor positioning systems is on the rise. People are looking for ways to locate objects, find seats in large venues, and explore their surroundings, and indoor positioning systems offer a solution to these needs.

While the Global Positioning System (GPS) has proven to be highly reliable and accurate in outdoor localization, it faces significant limitations in indoor settings. The detection and decoding of GPS signals in indoor environments are challenging due to signal attenuation caused by physical obstacles such as walls and ceilings. As a result, researchers have proposed and discussed various alternative technologies for indoor localization. Despite much research into alternatives to GPS, none of these technologies have made a substantial impact in the field, and no standard technology has emerged for indoor localization, as GPS has for outdoor localization.

One technology that has been gaining attention in recent years is Bluetooth Low Energy (BLE). BLE technology has been recognized as having high potential for performing indoor localization, and it is the focus of this project. BLE beacons can be deployed at specific locations to estimate the location of a drone or any object using Received Signal Strength Indication (RSSI) techniques and trilateration methods. This

technology offers greater accuracy and potential applications in various fields such as defense, inventory management, airports, and underground locations. As the cost of BLE beacons and drones continues to decrease, this technology has the potential to revolutionize the way UAVs are utilized in these industries.

In conclusion, indoor positioning systems are becoming increasingly important in our daily lives, and the demand for accurate and reliable localization solutions is on the rise. While GPS has proven to be highly effective in outdoor environments, it faces significant limitations in indoor settings. BLE technology offers high potential for indoor localization and is the focus of this project. The outcomes of this project aim to assist the feasibility analysis of the use of current Bluetooth Low Energy technology in the context of indoor localization to find the position of a drone or any object. With the potential to revolutionize various industries, this technology offers exciting opportunities for innovation and development.

1.1 INDOOR POSITIONING SYSTEM

Indoor positioning systems (IPS) are used to track the location of people or objects inside buildings. They use various technologies such as Wi-Fi, Bluetooth, RFID, and ultrasonic waves to accurately determine the position of the object or person. IPS can be used for various purposes such as finding your way inside a building, tracking assets, ensuring security, and providing context-aware services.

However, IPS face challenges such as signal interference, reflections of signals from different surfaces, and the lack of a standard approach for setting up and calibrating them. Additionally, each technology has its own strengths and weaknesses, such as accuracy, cost, power consumption, and complexity of deployment. Hence, the choice of technology for a particular application depends on various factors such as the surroundings, the user's needs, and the cost-benefit analysis. It is essential to choose the right technology to ensure the accurate functioning of the system.

1.2 TRENDS AND FUTURES

The Emerging Trends in Indoor Positioning Systems are

- *Integration with IoT:* IPS are being integrated with other smart building technologies, such as IoT, to create a more comprehensive understanding of the indoor environment.
- *Improved accuracy:* IPS solutions are using advanced algorithms and machine learning techniques to provide more precise location information.
- *Standardization:* There is a growing need for standardization in IPS technologies to ensure interoperability and seamless integration with other systems.
- *Real-time tracking:* Real-time tracking capabilities are becoming more important in IPS, especially in logistics and asset tracking applications.
- *Privacy and security:* The latest IPS solutions incorporate features such as encryption and user consent mechanisms to ensure the protection of personal data.

The future of indoor positioning systems is driven by the need for more accurate, reliable, and scalable solutions, as well as the integration with other smart building technologies, such as the Internet of Things (IoT), artificial intelligence (AI), or edge computing. Some of the trends and directions for the future of IPS include:

- Integration with other sensors and data sources, such as cameras, occupancy sensors, or environmental sensors, to provide a more holistic view of the indoor environment and enhance the user experience.
- Use of machine learning and AI algorithms to improve the accuracy and robustness of IPS, by learning from the past data and predicting the future movements of the tracked objects.
- Adoption of edge computing and fog computing architectures, which enable the processing and analysis of data at the edge of the network, closer to the source, and reduce the latency and bandwidth requirements.
- Standardization and interoperability of IPS technologies, to enable seamless integration and exchange of data across different systems and platforms.

CHAPTER – 2

LITERATURE SURVEY

This chapter provides a detailed literature survey related to the project, Literature summary, Problem definition, Objectives of the project. As many people have started working on the indoor positioning systems (IPS), it has become very popular in recent years. So I have collected some references and came up with the project which will have more accuracy and real time data visualization using trilateration and RSSI radio signal indicator. Here some of the references related to the indoor positioning systems.

2.1 INTERFERENCE FROM THE LITERATURE SURVEY

Fabio Ciravegna (2020) et al. present the work on a Bluetooth Low Energy (BLE) based indoor positioning system developed for monitoring the daily living pattern of old people (e.g. people living with dementia) or individuals with disabilities. The proposed sensing system is composed of multiple sensors that are installed in different locations in a home environment. The specific location of the user in the building has been pre-recorded into the proposed sensing system that captures the raw Received Signal Strength Indicator (RSSI) from the BLE beacon that is attached to the user. Two methods are proposed to determine the indoor location and the tracking of the users: a trilateration-based method and fingerprinting based method. Experiments have been carried out in different home environments to verify the proposed system and methods. The results show that our system is able to accurately track the user location in home environments and can track the living patterns of the user which, in turn, may be used to infer the health status of the user. Our results also show that the positions of the BLE beacons on the user and different quality of BLE beacons do not affect the tracking accuracy.

HAIYUN YAO (2020) et al proposed the work on an integrity monitoring (IM) algorithm based on the parity vector and Maximum Likelihood Estimation Gross Error test (MLEGE) for indoor positioning using Bluetooth Low Energy (BLE) beacons. The proposed IM algorithm has achieved significant improvements on the BLE positioning accuracy and positioning robustness. This IM algorithm can identify and eliminate two

gross errors simultaneously to improve positioning accuracy during the positioning process; most important of thing, the IM provides one technique of timely alert when the positioning system is unavailable due to the positioning accuracy no longer satisfies user requirement. A series of simulation and field experiments were conducted to evaluate the performance of the IM algorithm.

Jesus Urena (2019) et al presented the work on the different challenges facing the design of an acoustic local positioning system in order to achieve suitable performance. The description of this design process has been focused on both low-level and high-level signal processing. In the first case, the waveform conformation (coding and modulation) and the processing of the received signal involve significant issues in order to address drawbacks, such as multipath conditions, multiple access interference, near– far effects, or Doppler shifting. Conversely, high-level processing is often related to the distribution of beacons, easy deployment, and calibration and positioning algorithms, including the possible fusion of information obtained.

Kanakaraj (2022) et al presented the work on the Hybrid Technology is implemented. The BLE with LoRa Tracker to know the position in Indoor localization, with the help of an IoT dashboard through LoRaWAN and TTN. The results are depicted on the screen on the map, by this Hybrid Technology, and 89.5% accurate position of the object or person is achieved. This Hybrid technology can cover up to ten to hundreds of kilometers. This technology can be used in warehouses or offices or universities, or showrooms.

KaisMekki (2019) et al they proposed an indoor positioning system (IPS) based on BLE technology and MQTT protocol. RSSI techniques combined with trilateration methodology are used to estimate the position of a mobile device based on a 2-parts linearization algorithm. A number of experiments are performed to analyze the distance accuracy and trilateration efficiency with the use of BLE-GeoMarkers. MQTT is also experimented for communication delay between the user and mobile devices. The results concluded that the system offers efficient position estimation with an accuracy of less than 1.5 meters which is relevant for many IoT applications. In the future, we plan to extend the experiment by evaluating other properties of our IPS such as energy

consumption and scalability. In addition, we plan to analyze the impacts of other RSSI filters such as Kalman and Chebychev theorem.

Mathan Kumar Balakrishnan (2017) et al In this proposed project the idea was to begin with beacon technology (Bluetooth low Energy), and by receiving RSSI data from beacons, to apply a filter to the RSSI data and finally use the trilateration method to find the position of an object (mobile phone or Raspberry pi). The filtering was performed using a Kalman filter. The purpose of the experimental tests was to test the accuracy of trilateration for a small environment, and the ability to pinpoint the drone or Bluetooth device position This test was used to see how accurate the location of an object (Bluetooth device) could be found using by trilateration of the estimated ranges to the Bluetooth beacons. It was observed that the RSSI signal noise level obtained with the smartphone is high. Even with the Kalman filter, errors of approximately 2m were observed, which is not enough to allow safe indoor flight of a drone. This large error value may be partially explained by the fact that the Bluetooth device was being held by the candidate. Therefore, the results obtained with the proposed system, using the Kontakt beacons, do not meet the requirements presented by the company. There is still room to improve this system's performance like deploying more BLE beacons and more elaborate filtering 46 algorithms. The low cost of the Kontakt beacons mean the system can be cost effective, and would be a solid foundation for other low cost applications to build upon.

Maxim Van de Wynckel (2021) et al They presented the OpenHPS framework and its use as an indoor positioning solution. They used a server with socket endpoints that stores fingerprints and fuses WLAN and BLE data to a predicted position that is transmitted back to the mobile application where it is fused with processed IMU data. They have illustrated the modularity with our symbolic spaces that build on top of the OpenHPS core component to provide symbolic locations, similar to HyLocSys Different from related hybrid positioning frameworks offering specific location providers, They demonstrated how nodes in the OpenHPS process network can be constructed and configured to support various technologies. For our indoor positioning demonstration, I recorded a new open source dataset of a single floor in our research lab with help of the OpenHPS framework. The dataset contains WLAN, BLE and IMU sensor data in different orientations and multiple walking trajectories. Using this dataset, They

showed how the process network can easily be adapted to optimize the behavior of the positioning algorithms for symbolic space hit rate or the latency in a trajectory. In future work they plan to further increase the flexibility by supporting different types of users, ranging from developers to less-technical end users who want to use OpenHPS for asset tracking. While these symbolic spaces support multiple floors, they might further explore the challenges of performing floor detection in a building. Overall, OpenHPS has proven its flexibility in handling an indoor positioning use case with modular layers of abstraction such as symbolic spaces or high-level API endpoints.

NoppapadonPakanon (2020) et al In this paper, they proposed the study of the accuracy of the trilateration method for indoor positioning with BLE beacons is presented. The accuracy obtained from one, average five and average ten measurements are studied. From the results, when the number of measurements is increased, the distance error tends to decrease. The multiple measurements of RSS can be used to improve the indoor position accuracy because the average RSS decreases the effect of multipath fading that occurs in the indoor environment.

Pérez (2019) et al They have presented a survey of different works regarding UAV localization in indoor environments. Indoor UAV implies an interesting field due to the variety of sensor technologies that can be applied and the difficulties they have to face: drone velocity, strong multipath, NLOS, computational load, etc. Trends point to the use of hybrid systems that use complementary technologies such as SOP signals and inertial navigation, ultrasound and IMU or UWB and cameras. They have also presented some preliminary tests based on ultrasonic signals.

Petros Spachos (2020) et al they proposed the work on a BLE localization technology for an IoT-based smart museum was presented. The proposed system uses BLE beacons to improve the interaction in a museum. iBeacons were used to provide proximity and localization services. An Android application was also developed to examine the performance of the system. The system was designed to work without Internet connection, however, its accuracy can be increased if access to a cloud server is provided. These experiments were conducted to measure the performance under different scenarios. The experimental results are promising. BLE beacons can improve

the interaction in a museum with low cost and without creating any interference with other wireless infrastructures in the area

Sophia.S (2021) et al presented the work to implement in indoor navigation using ESP32. The approximate location of the user is identified by putting three ESP32 transmitters at a specific spot. This is accomplished by calculating the distance between known position transmitters and the RSSI of the transmitters. They get the estimated position of the user in coordinate format by giving the fetched data in octave for Trilateration. Our extensive research goal is to improve indoor location accuracy by using filters to soften the RSSI. In addition, we want to develop an app that can identify the correct location and provide directional aid to the user.

Thai-Mai Thi Din (2021) et al They proposed a novel real-time indoor positioning system in smartphones based on the BLE iBeacon signal. They used embedded sensors for displacement calculation and BLE iBeacon signal as a calibrated opportunity for sensor-based IPS in this work. Firstly, they investigate the problems associated with RSS's uncertainty and then offer a solution for RSS-based locating moving targets under a low sampling rate. Secondly, They proposed a method of improving accuracy for the LSE method. Improved LSE-based position is fused with PDR-based position using Kalman filter to produce more accurate positions. The proposed approaches' accuracy proved a great persuasion for service providers to deploy this low-complexity system for various location-based services. Finally, this work provides valuable insight into the strengths and weaknesses of a smartphone-based indoor positioning system using the BLE.

2.2 LITERATURE SUMMARY

Based on surveys that have been mentioned above, the existing system is quite complicated and expensive and cannot be accessed by ordinary people. Only large-scale industries can work on it. I was developing a product that would be easily accessible by everyone with less knowledge of technology with more accuracy.

2.3 PROBLEM DEFINITION

GPS (Global Positioning System) and GSM (Global System Mobile Communication) technology do not work over closed areas in order to monitor and track closed areas over industry. It's a huge problem in real time implementation. The product we develop will solve the problem and can be used in real-time.

2.4 OBJECTIVES OF THE PROJECT

- To identify the base nodes and interconnect them with the cloud.
- Connecting Tags with Base Nodes.
- Collect the data from base nodes processed by the controller and be able to locate tags.

CHAPTER – 3

AIM AND SCOPE OF PRESENT INVESTIGATION

This chapter provides an overview of the aim and scope of the present investigation, which is focused on developing an indoor positioning system using Bluetooth Low Energy (BLE) technology. The area of the project and its applications will also be discussed, highlighting the potential use cases for this technology. Additionally, we will review the existing work in this area and identify the limitations of the current approaches.

3.1 PROPOSED METHODOLOGY -RSSI

RSSI (Received Signal Strength Indicator) is a commonly used technique for estimating the distance between an ESP32 beacon and a user's device in indoor positioning systems (IPS). Here is a proposed methodology for using RSSI in your project:

1. *Set up the ESP32 beacons:* The first step is to set up the ESP32 beacons in the lab or indoor space. The beacons can be programmed to transmit a signal at a regular interval. The signal strength will depend on the distance between the beacon and the user's device.
2. *Measure the RSSI:* The user's device can scan for the beacon signals and measure the RSSI. The RSSI is a value that represents the strength of the signal received by the device. The RSSI value can be used to estimate the distance between the beacon and the user's device using a mathematical formula.
3. *Calibrate the RSSI:* The RSSI value can be affected by many factors, including interference from other devices, obstacles in the environment, and the orientation of the user's device. To improve the accuracy of the distance estimate, it is necessary to calibrate the RSSI values. This can be done by collecting RSSI data at various distances from the beacon and using the data to develop a calibration curve.

4. *Calculate the user's location:* Once the RSSI values have been calibrated, they can be used to estimate the distance between the user's device and the beacons. Multiple beacons can be used to triangulate the user's location using a trilateration algorithm. The estimated location can be displayed on a map or used to provide location-based information to the user.
5. *Display QR codes:* QR codes can be displayed at the user's location to provide information about the lab or equipment in the lab. The QR codes can be scanned using the user's device to display the information.

Overall, using RSSI for indoor positioning in your project can be a reliable and cost-effective solution. However, it is important to calibrate the RSSI values to improve the accuracy of the distance estimate. Triangulation using multiple beacons can be used to calculate the user's location, and QR codes can be used to provide location-based information to the user.

3.2 AREA OF PROJECT AND APPLICATION

The area of your project is indoor positioning and wayfinding using an ESP32 beacon and QR codes. The project has many potential applications, including:

1. *Campus navigation:* The system can be used to help students and visitors navigate around a campus, locate specific buildings, and find their way to classrooms, labs, and other facilities.
2. *Retail:* In a retail environment, the system can be used to guide customers to specific products or departments. It can also be used to provide information about products and promotions through QR codes.
3. *Healthcare:* The system can be used in hospitals and clinics to guide patients to their appointments, locate medical equipment, and provide information about medical procedures.
4. *Museums and galleries:* The system can be used to guide visitors around exhibits, provide information about artworks or artifacts, and create interactive experiences.

5. *Manufacturing:* In a manufacturing facility, the system can be used to guide workers to specific workstations or equipment. It can also be used to track the location of equipment and materials.
6. *Defence:* In defence it can be used for tracking and monitoring the movement of troops, equipment, and assets in a military base or a secure facility.

In the project specifically, the application is indoor positioning and wayfinding in a laboratory setting. The system can help researchers and students navigate around the lab, locate specific equipment or materials, and access information about the lab and its equipment through QR codes. This can improve efficiency and productivity in the lab, as well as enhance the learning experience for students. Additionally, the system can be used to track the location of valuable equipment, helping to prevent theft or loss.

3.3 TRIANGULATION

Triangulation is a common technique used in indoor positioning systems to determine the location of a user based on the signals received from multiple beacons. In your project, you can use triangulation to estimate the location of a user based on the RSSI values received from three or more ESP32 beacons. Here's how triangulation works in your project:

1. *Measure the RSSI:* The first step is to measure the RSSI values between the user's device and multiple ESP32 beacons. The RSSI values represent the strength of the signal received from each beacon and can be used to estimate the distance between the user's device and each beacon.
2. *Calculate the distances:* Once you have the RSSI values, you can use a mathematical formula to estimate the distance between the user's device and each beacon. This formula takes into account the signal strength, frequency, and other factors that affect the signal.
3. *Determine the user's position:* To determine the user's position, you need to find the intersection of three or more circles, with each circle centered at a different

beacon and with a radius equal to the estimated distance between the beacon and the user's device. The intersection point represents the estimated location of the user.

4. *Calibrate the system:* To improve the accuracy of the system, it's important to calibrate the RSSI values and distances for each beacon. You can do this by collecting data at different distances from each beacon and using this data to create a calibration curve. The calibration curve can be used to adjust the distance estimates based on the RSSI values.
5. *Display the user's position:* Once you have determined the user's position, you can display it on a map of the laboratory or display the lab information and QR code associated with that specific location.

Triangulation can provide accurate indoor positioning in your laboratory setting, but it requires careful calibration of the RSSI values and distances to improve the accuracy of the system. By using triangulation, you can provide users with location-based information about the laboratory and its equipment, improving efficiency and productivity in the lab.

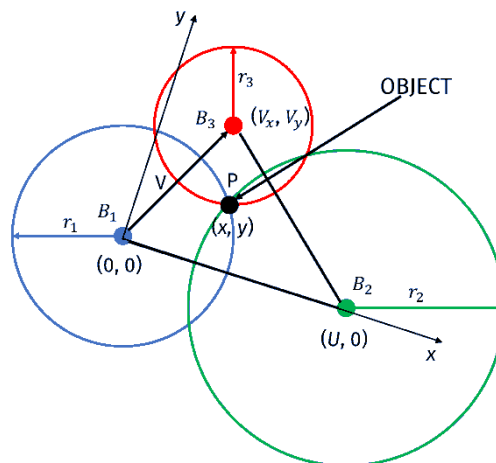


Fig 3.1: Triangulation

3.4 EXISTING WORK

There have been existing works on indoor positioning systems that use Bluetooth Low Energy (BLE) beacons or Wi-Fi signals to estimate a user's location. Here are a few examples:

1. *Estimate Indoor Location*: Estimate Indoor Location is a popular indoor positioning system that uses BLE beacons to provide accurate location tracking in indoor environments. The system uses a combination of fingerprinting and trilateration techniques to estimate the user's location based on the signals received from multiple beacons.
2. *Apple iBeacon*: Apple's iBeacon technology is another popular solution for indoor positioning. iBeacons use BLE technology to broadcast a signal that can be detected by nearby devices, which can then be used to estimate the user's location.
3. *Open Beacon*: Open Beacon is an open-source indoor positioning system that uses Wi-Fi signals to estimate a user's location. The system works by measuring the signal strength of nearby Wi-Fi access points and using this information to estimate the user's location.
4. *RTLS*: Real-time location systems (RTLS) are another type of indoor positioning system that use a variety of technologies, including Wi-Fi, RFID, and ultrasound, to estimate a user's location. These systems can be used in a wide range of applications, including healthcare, retail, and manufacturing.

In the project, I was using an ESP32 beacon to estimate the user's location based on the RSSI values received from multiple beacons. This approach is similar to the trilateration technique used in Estimate Indoor Location and Apple iBeacon. However, your project is unique in its application to a laboratory setting and the use of QR codes to provide location-based information to users.

3.5 DISADVANTAGE OF EXISTING WORK

While indoor positioning systems (IPS) offer many potential benefits, there are several disadvantages associated with the current IPS technologies available on the market. These drawbacks should be considered when evaluating the potential use of an IPS in a specific application.

One disadvantage is accuracy. Although IPS can provide reasonably accurate location information, they can still be prone to errors due to signal interference, multipath propagation, and other environmental factors. For example, the accuracy of Wi-Fi-based IPS can be affected by the presence of walls or other obstacles that can cause the signal to reflect or scatter.

Another disadvantage is cost. Some existing IPS, such as Estimote Indoor Location and Apple iBeacon, can be expensive to deploy and maintain, particularly in large-scale indoor environments. The cost of these systems can include not only the hardware but also the software and infrastructure needed to support them.

Deployment complexity is another challenge associated with IPS. Deploying these systems can be a complex and time-consuming process, requiring the installation of multiple beacons or access points throughout the indoor environment. This process can be particularly challenging in complex indoor environments with many rooms or floors.

Limited range is also a drawback of some IPS technologies. Bluetooth Low Energy (BLE) and Wi-Fi signals can have a limited range, which can limit the coverage area of these systems. This limitation can be particularly problematic in large indoor environments, where a high density of beacons or access points may be required to ensure accurate positioning.

Compatibility issues can also be a challenge with existing IPS. Some IPS technologies may not be compatible with all types of mobile devices or operating systems, which can limit their usefulness in certain settings. This limitation can be particularly problematic in settings where multiple types of devices are used or where users have a wide range of mobile devices.

Finally, privacy concerns are a significant issue with IPS that collect and store location data. The collection and storage of this data may raise privacy concerns for users, particularly if the data is not adequately protected. It is important to ensure that adequate privacy safeguards are in place when deploying an IPS in a specific setting.

3.6 PROPOSED TRIANGULATION USING DISTANCE FROM RSSI

Triangulation using the distance calculated from RSSI values is a technique used in indoor positioning systems. This approach estimates a user's location by measuring the signal strength of multiple beacons and calculating the distance between the user and each beacon based on the RSSI value.

Here is a proposed methodology for triangulation using distance from RSSI:

1. *Collect RSSI data:* The first step is to collect RSSI data from multiple beacons placed in the laboratory. The beacons should be placed at known locations, such as the corners of the room, and their coordinates should be recorded.
2. *Calculate distance:* The distance between the user and each beacon can be calculated using the RSSI values and a path loss model. There are several path loss models available, such as the log-distance path loss model or the propagation model, which can be used to estimate the distance based on the RSSI value.
3. *Triangulation:* Once the distances between the user and each beacon are calculated, the user's location can be estimated using triangulation. Triangulation involves using the distance between the user and at least three beacons to calculate the user's position. The user's location can be calculated using various methods, such as the intersection of circles or the centroid of the triangle formed by the three beacons.
4. *Calibration:* The triangulation algorithm can be calibrated to improve accuracy by using a set of reference points with known coordinates. The algorithm can be trained to adjust for any errors or variations in the RSSI values to improve the accuracy of the estimated position.

CHAPTER – 4

PROPOSED METHODOLOGY

This chapter provides an overview of the materials and methods used in the development of the IPS system. The proposed system and its advantages are discussed, along with a block diagram of the IPS system. The chapter also covers the hardware and software description of the system, and the cost estimation of the project. By the end of this chapter, readers will have a clear understanding of the technology used and the development process of the IPS system.

4.1 PROPOSED SYSTEM

The proposed indoor positioning system for the laboratory environment involves the use of ESP32 Bluetooth Low Energy (BLE) beacons placed at specific locations throughout the laboratory. These beacons transmit a unique signal that is detected by a mobile device equipped with Bluetooth capabilities. By measuring the Received Signal Strength Indicator (RSSI) of the beacon signals, the mobile device can estimate its distance from each beacon and use trilateration techniques to determine its location within the laboratory. The system also utilizes QR codes placed at specific locations within the laboratory to provide users with location-based information and instructions on their mobile devices. The system is designed to be easy to deploy and maintain, with low cost and complexity compared to existing indoor positioning systems.

4.2 PROPOSED SYSTEM ADVANTAGES

1. *Accuracy:* The use of multiple beacons and QR codes can provide more accurate location tracking compared to systems that rely solely on signal strength measurements.
2. *Low cost:* The proposed system is relatively low-cost compared to other IPS that use expensive hardware and software.
3. *Easy deployment:* The system can be easily deployed in various indoor settings without the need for complex installation procedures.

4. *Scalability*: The proposed system can be easily scaled up or down depending on the size of the indoor environment, making it suitable for a wide range of applications.
5. *Customizable*: The system can be customized to provide location-based information specific to the needs of the user or application.
6. *Compatibility*: The proposed system is compatible with most smartphones and tablets that have a Bluetooth connection.
7. *Privacy*: The proposed system does not store user location data, reducing potential privacy concerns for users.

4.3 BLOCK DIAGRAM OF THE IPS

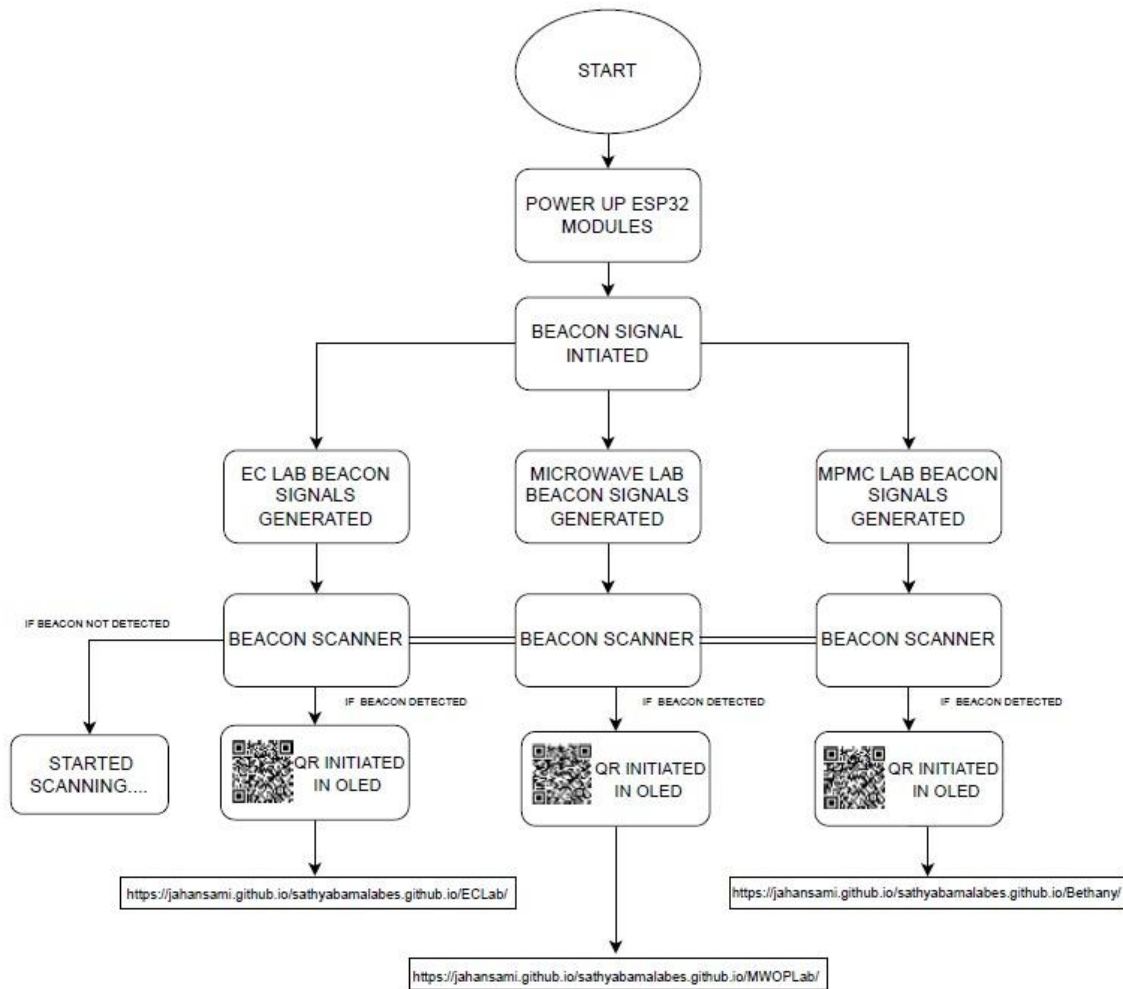


Fig 4.1: Block Diagram Of The IPS

4.4 HARDWARE DESCRIPTION

The indoor positioning system (IPS) developed for this project utilizes an ESP32 microcontroller, which serves as the central processing unit for the system. The ESP32 is equipped with Bluetooth Low Energy (BLE) and Wi-Fi capabilities, which allow it to detect and communicate with nearby beacons and access points. The beacons used in this system are small, low-power devices that emit a Bluetooth signal at regular intervals. The system also uses a camera-equipped device, such as a smartphone or tablet, to scan QR codes located throughout the indoor environment.

In addition to the ESP32 and beacons, the system also includes a power source, such as a battery or AC adapter, to provide power to the ESP32 and beacons. The system may also include mounting hardware or stands to secure the beacons in place throughout the indoor environment. Overall, the hardware components used in this system are cost-effective and easily accessible, making it an affordable and practical solution for indoor positioning systems.

4.4.1 ESP

The ESP (Embedded Systems Processor) is a family of low-cost, low-power microcontrollers that are widely used in the field of embedded systems and IoT devices. Developed by Espressif Systems, the ESP microcontrollers are based on the Xtensa LX6 processor architecture and are known for their small form factor, low power consumption, and high level of integration.

One of the most popular members of the ESP family is the ESP8266, which has gained widespread adoption in the maker and hobbyist communities due to its low cost and ease of use. The ESP8266 is a Wi-Fi enabled microcontroller that can be programmed using the Arduino IDE or other programming environments, making it a popular choice for a wide range of IoT applications.

Other members of the ESP family, such as the ESP32 and ESP32-S2, offer even more features and capabilities, including Bluetooth connectivity, dual-core processors, and more advanced power management options. Overall, the ESP family of microcontrollers provides a powerful and flexible platform for building a wide range of embedded systems and IoT devices.

4.4.2 ESP32

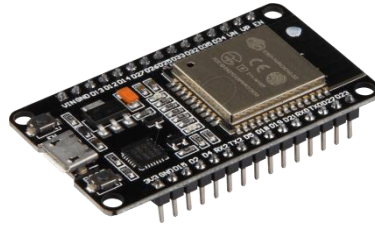


Fig 4.2: ESP32

ESP32 is a more advanced version of the ESP8266, featuring a dual-core processor, more memory, and additional peripherals. It is a low-power Wi-Fi and Bluetooth-enabled system-on-a-chip (SoC) that can be used in a wide range of applications.

One of the key advantages of the ESP32 over the ESP8266 is its dual-core processor, which allows for more efficient multitasking and performance. It also has more memory (up to 520 KB SRAM), which can be helpful for larger projects and more complex programs. Additionally, the ESP32 includes more peripherals such as I2C, SPI, UART, ADC, and DAC, making it more versatile than the ESP8266.

In terms of power consumption, the ESP32 also has an advantage, with a variety of low-power modes and optimizations that can extend battery life. It also supports a wider range of Wi-Fi and Bluetooth protocols, including Bluetooth Low Energy (BLE), which is becoming increasingly popular for IoT devices.

In my project, I chose to use the ESP32 due to its superior performance, memory, and versatility. As my project requires Bluetooth connectivity and low-power modes, the ESP32 was a better choice than the ESP8266. Ultimately, my decision to use the ESP32 depended on the specific needs of my project and the features that were most important to me.

PIN DIAGRAM

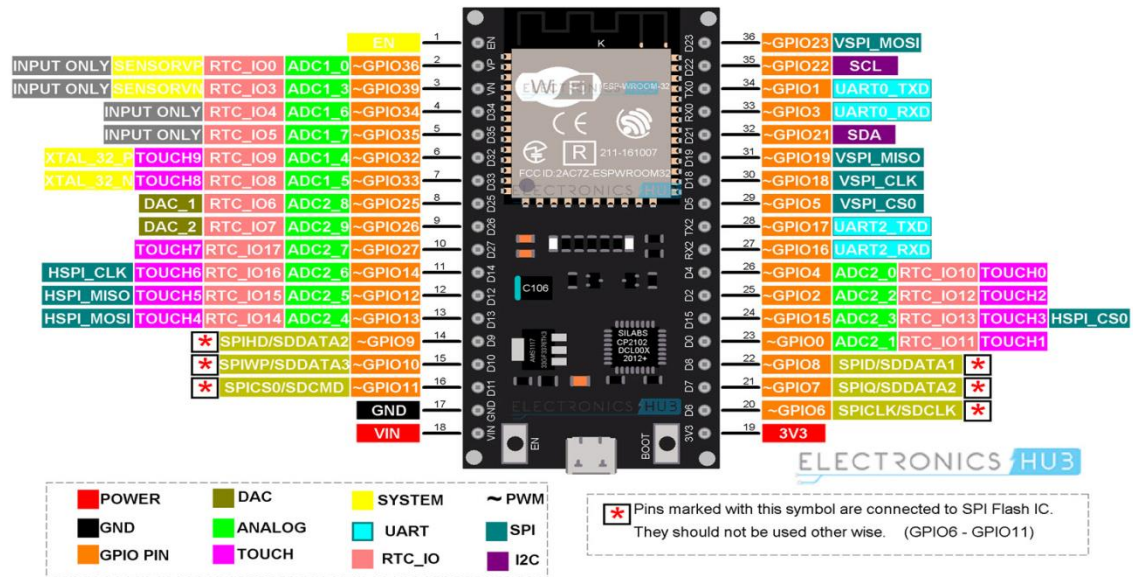


Fig 4.3: Pin Diagram

The ESP32 chip features 34 physical GPIO pins (GPIO0 ~ GPIO19, GPIO21 ~ GPIO23, GPIO25 ~ GPIO27, and GPIO32 ~ GPIO39). Each pin can be used as a general-purpose I/O, or be connected to an internal peripheral signal.

Digital Pins

The ESP32 has a total of 34 digital pins. These pins are similar to Arduino digital pins which allows you to add LED display, OLED display, sensors, buttons, buzzers, etc. to our projects.

Most of these pins support the use of internal pull-up, pull-down, and high impedance status as well. This makes them ideal for connecting buttons and matrix keyboards, as well as for applying LED control techniques such as the well-known Charlieplexing.

ESP32 WROOM module has 25 GPIO pins out of which there are only input pins, pins with input pull up and pins without internal pullup. Maximum current drawn per a single GPIO is 40mA according to the "Recommended Operating Conditions" section in the ESP32 datasheet.

Hardware Specifications

- Dual-core 32-bit microprocessor running at up to 240 MHz
- 520 KB SRAM and 4 MB flash memory for program and data storage
- Integrated Wi-Fi and Bluetooth connectivity, including support for BLE and Classic Bluetooth
- 12-bit analog-to-digital converter (ADC) with up to 18 channels
- 2x8 bit digital-to-analog converters (DAC)
- 34 GPIO pins, including capacitive touch sensors, PWM outputs, and interrupt pins
- UART interfaces, 3 SPI interfaces, 2 I2C interfaces, and SDIO interface
- Integrated temperature sensor and hall effect sensor
- Secure boot and flash encryption for improved security
- Low-power modes for battery-operated devices

4.4.3 OLED Display

The acronym 'OLED' stands for Organic Light-Emitting Diode - a technology that uses LEDs in which the light is produced by organic molecules. These organic LEDs are used to create what are considered to be the world's best display panels. OLED displays are made by placing a series of organic thin films between two conductors. When an electrical current is applied, a bright light is emitted. A simple design - which brings with it many advantages over other display technologies.

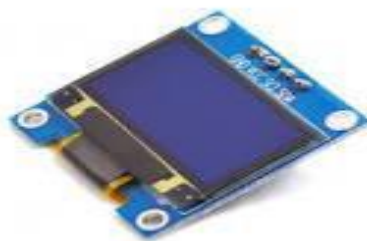


Fig 4.4: OLED Display

OLED Display OLEDs enable emissive displays - which means that each pixel is controlled individually and emits its own light (unlike LCDs in which the light comes

from a backlighting unit). OLED displays feature great image quality - bright colors, fast motion and most importantly - very high contrast. Most notably, “real” blacks (that cannot be achieved in LCDs due to the backlighting). The simple OLED design also means that it is relatively easy to produce flexible and transparent displays.

4.5 SOFTWARE DESCRIPTION

4.5.1 Arduino IDE

Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board.

The Arduino platform has become quite popular with people just starting out with electronics, and for good reason. Unlike most previous programmable circuit boards, the Arduino does not need a separate piece of hardware (called a programmer) in order to load new code onto the board -- you can simply use a USB cable. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program. Finally, Arduino provides a standard form factor that breaks out the functions of the micro-controller into a more accessible package.



Fig 4.5 Arduino IDE logo

It is available for Windows, macOS, and Linux operating systems and can be downloaded for free from the Arduino website. It is based on the Processing programming language and provides a user-friendly interface for writing code. It has a simple and intuitive design that makes it easy for beginners to get started with programming. The IDE comes with a number of built-in libraries that make it easy to interface with sensors, motors, and other electronic components.

One of the key features of the Arduino IDE is the Serial Monitor. This is a built-in tool that allows users to communicate with the Arduino board through a serial connection. It is a valuable debugging tool that can be used to test and troubleshoot code, as well as monitor sensor readings and other data.

It also includes a number of other useful features, such as syntax highlighting, code completion, and automatic indentation. These features make it easier to write clean and well-structured code, which can save time and reduce errors.

Another key feature of the Arduino IDE is its ability to interface with external libraries. Users can easily download and install libraries that provide additional functionality for their projects. There are thousands of libraries available for Arduino boards, covering everything from Bluetooth communication to advanced control of motors and servos.

It also provides a powerful and flexible platform for uploading code to the Arduino board. Users can choose from a range of upload methods, including USB, Bluetooth, and Ethernet. The IDE also provides a range of debugging tools that can be used to troubleshoot code and monitor system performance.

In addition to its core features, the Arduino IDE also has a thriving community of users and developers. There are countless tutorials, forums, and resources available online, making it easy to find help and support for any aspect of Arduino programming.

4.5.2 Fusion 360

Fusion 360 is a 3D based modeling software, capable of modeling, simulation, and documentation. It was developed by AutoCAD in 2013, and is a cloud-based system with a top-down approach. This means that it allows the users to create larger

structures, which are then broken down into smaller components. The user can tweak each specific component to their liking and requirement.



Fig 4.6 Fusion 360 logo

Fusion 360 is a relatively young software, and it is capable of:

- Parametric Modelling
- Mesh Modelling
- Surface Modelling
- CAD and CAM integration
- Extremely realistic renders
- Printed Circuit Board (PCB) layout, planning and manufacturing
- Cooling of electronics
- Topology and shape optimisation

What are the Benefits of Fusion 360?

Fusion 360 comes with a huge range of benefits. These include:

- User Interface
- Integrated Electronics
- Designed to Innovate

4.5.3 GITHUB

GitHub is a web-based version control and collaboration platform for software developers. Microsoft, the biggest single contributor to GitHub, acquired the platform for \$7.5 billion in 2018. GitHub, which is delivered through a software as a service

(SaaS) business model, was started in 2008. It was founded on Git, an open source code management system created by Linus Torvalds to make software builds faster.

Git is used to store the source code for a project and track the complete history of all changes to that code. It lets developers collaborate on a project more effectively by providing tools for managing possibly conflicting changes from multiple developers.

GitHub allows developers to change, adapt and improve software from its public repositories for free, but it charges for private repositories, offering various paid plans. Each public and private repository contains all of a project's files, as well as each file's revision history. Repositories can have multiple collaborators and can be either public or private.



Fig 4.7 GITHUB logo

The following are some important terms GitHub developers use:

- Fork
- Pull request
- Merge
- Push
- Commit
- Clone

Benefits and features of GitHub

GitHub facilitates collaboration among developers. It also provides distributed version control. Teams of developers can work together in a centralized Git repository and track changes as they go to stay organized.

GitHub offers an on-premises version in addition to the well-known SaaS product. GitHub Enterprise supports integrated development environments continuous

integration tools, as well as many third-party apps and services. It offers more security and auditability than the SaaS version.

Other products and features of note include the following:

- GitHub Gist
- GitHub Flow
- GitHub Pages
- GitHub Desktop
- GitHub Student Developer Pack
- GitHub Campus Experts
- GitHub CLI
- GitHub Codespaces

4.6 COST ESTIMATION OF THE PROJECT

Estimating the cost of implementing an indoor positioning system (IPS) based on ESP32 will depend on several factors such as the quantity and quality of components, software development, and any associated labor costs. Here's a breakdown of the estimated costs for the proposed system:

COST ESTIMATION	
Component	Price in Rupees
ESP 32	2000
OLED	300
3D Model case	250
Wires	50
Total	2600

Table 4.1: Cost Estimation

CHAPTER – 5

PROJECT IMPLEMENTATION

This chapter presents the implementation of the proposed IPS system, which includes the allocation of access points, setup of the scanner, deployment of nodes, and hosting of lab website. It provides a detailed description of the hardware and software used, along with the costs involved. The chapter also discusses the challenges faced during the implementation process and the solutions adopted.

5.1 ACCESS POINT ALLOCATION

For this project, three ESP32 devices will be used as access points. The access points will be positioned at strategic locations within the indoor environment to ensure optimal coverage and accuracy of the indoor positioning system. The allocation of access points will be based on factors such as the size and layout of the indoor space, potential sources of interference, and the range of the access points. The access points will be configured to broadcast signals at regular intervals, which will be received by mobile devices equipped with the IPS app. The app will then use these signals to determine the location of the mobile device in relation to the access points. Additionally, one ESP32 device will be connected to an OLED display, which will serve as the scanner for the system. The scanner will be used to detect the Wi-Fi signals broadcast by the access points and display the location information on the OLED display.

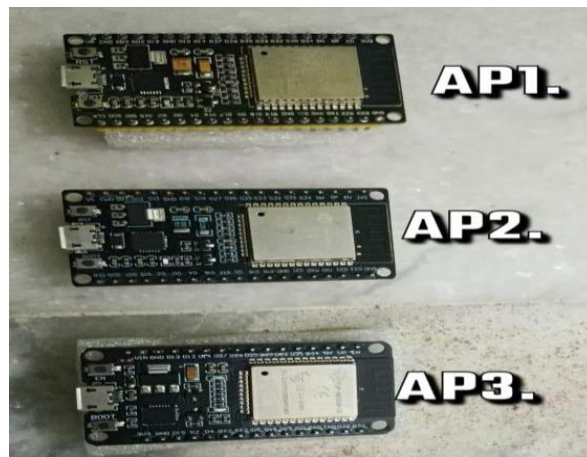


Fig 5.1 Three ESP32 Device

5.2 SCANNER SETUP

In order to display the output of the scanning process, an OLED display has been integrated with one of the ESP32 modules. The ESP32 module is responsible for the scanning process and sends the detected signals to the OLED display. The display has been configured to show the output in a clear and easily readable format. This provides a user-friendly interface for the operator to view the output of the scanning process. The OLED display is compact, lightweight, and consumes low power, making it an ideal choice for integration into the system. The display can be easily mounted onto the device, providing a convenient method for the operator to view the scanning results in real-time. Overall, the integration of the OLED display with the ESP32 module has greatly enhanced the functionality of the system and improved the overall user experience.

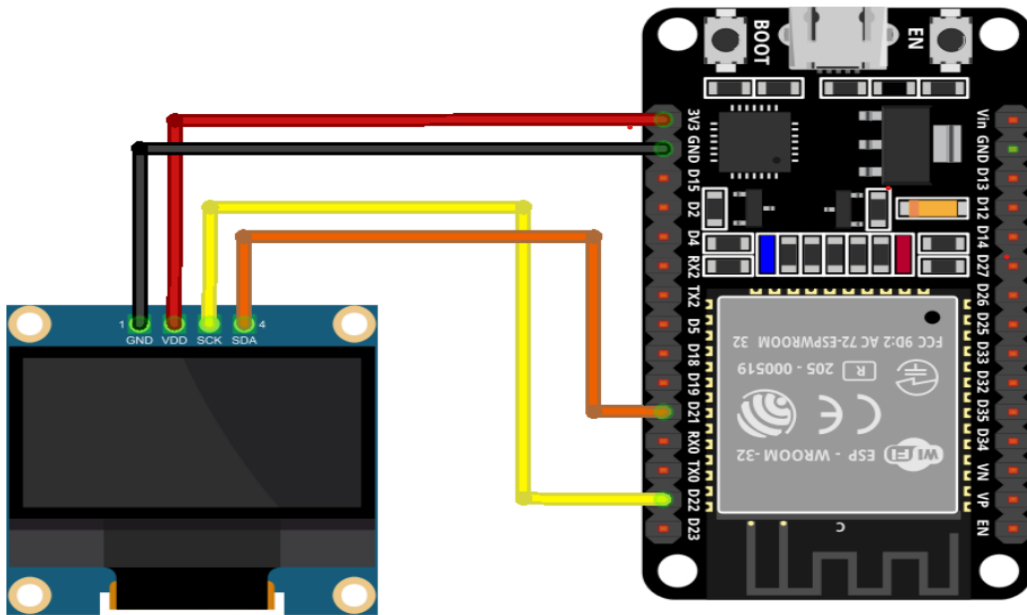


Fig 5.2 Connecting the ESP32 and OLED Display

5.3 NODE DEPLOYMENT

Node deployment is a crucial aspect of an indoor positioning system (IPS) project. In order to accurately determine the location of an object or person within a building, it is important to strategically place the nodes in optimal locations. The nodes

can be any device that can transmit or receive signals, such as Wi-Fi access points or Bluetooth beacons.

Before deploying the nodes, it is important to perform a site survey to determine the layout of the building, the presence of any obstacles, and any potential sources of interference. This information can be used to determine the optimal locations for the nodes, as well as the type and number of nodes required to cover the entire area.

Once the optimal locations have been identified, the nodes can be installed and configured. It is important to ensure that the nodes are placed in a stable and secure location, and that they are configured to transmit at the appropriate power level and frequency.

After the nodes have been deployed, it is important to perform testing to verify that the system is functioning correctly. This can involve walking around the building and monitoring the location accuracy of the system. If any issues are identified, adjustments may need to be made to the node placement or configuration.

5.4 LAB INFORMATION AND WEBSITE HOSTING

In our project, we have hosted the lab website on GitHub pages. This approach offers several benefits such as free hosting, easy setup, and the ability to use custom domains. The website provides detailed information about the lab, including its mission, research areas, and the staff members who work there. Additionally, the website features detailed descriptions of the lab's ongoing experiments and research projects.

One of the unique features of the website is that it includes a YouTube link for each experiment. This allows users to watch the experiment being conducted in real-time, providing an immersive experience that goes beyond traditional text-based descriptions.

The website also provides a contact section where users can get in touch with the staff members of the lab for any queries or collaborations. This section includes the email addresses of the staff members and links to their individual research pages.

To create the website, we used HTML, CSS, and JavaScript. The website's design is simple yet elegant, with a clean and modern layout that makes it easy for

users to navigate and find the information they need. The website is fully responsive, which means it can be accessed from any device, including desktops, laptops, tablets, and smartphones.

The use of GitHub pages for hosting the website has also made it easy to maintain and update the website. Whenever we need to make any changes or add new content, we can simply make the necessary changes to the GitHub repository, and the changes will be automatically reflected on the live website.

CHAPTER – 6

RESULT AND DISCUSSION

In this section, I present the results and discussion of our indoor positioning system using ESP32 as a beacon. I describe the outcomes of our experiments and analyses, including the accuracy of our location tracking algorithm and the performance of the system under various conditions. I also discuss the implications of these findings and suggest potential solutions to address limitations and challenges encountered during the development of the system.

6.1 STIMULATION RESULTS:

In the simulation, a BLE scanner app was used on a mobile phone to capture the RSSI values of the BLE beacons placed at different locations in the lab. The RSSI values were then plotted on a graph, which showed the signal strength of each beacon at various distances. The graph helped to identify the optimal locations for the BLE beacons, which were then placed accordingly in the lab.

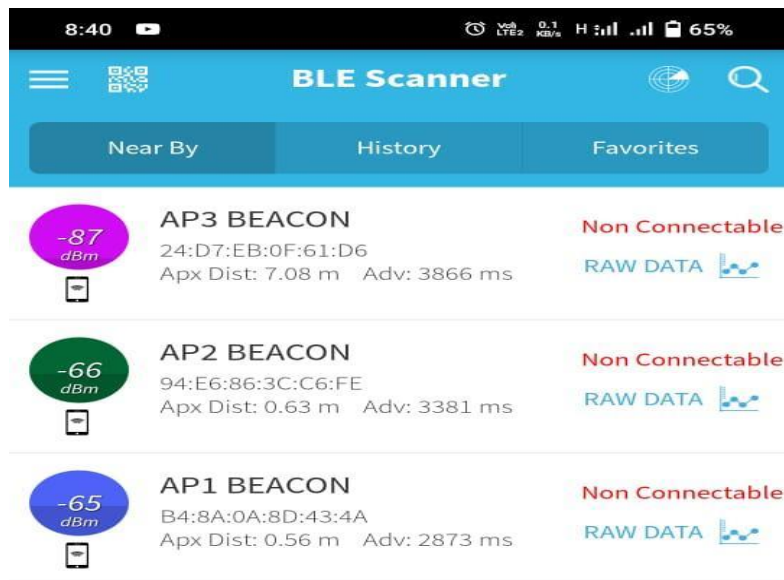


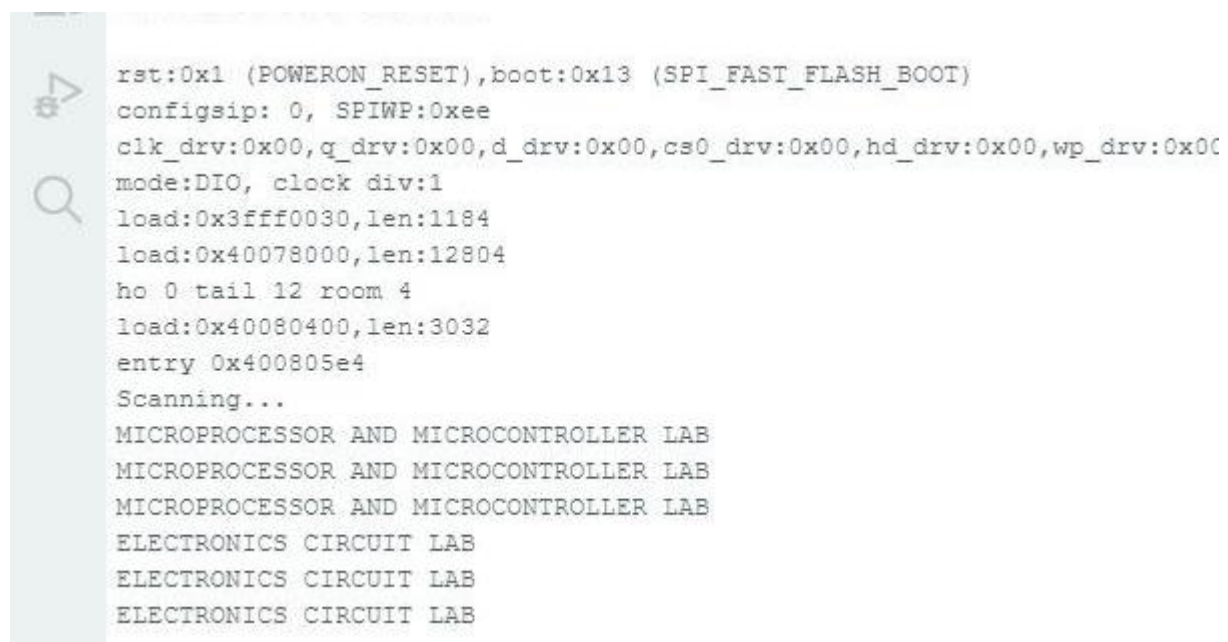
Fig 6.1: Finding RSSI on phone

Figure 6.1 shows the graph generated from the simulation, which illustrates the RSSI values of the BLE beacons. As seen in the image, the beacons placed in the corners had the highest signal strength, while the ones placed near the center had

relatively lower signal strength. The image helped in determining the appropriate placement of the BLE beacons for accurate IPS. Overall, the simulation was a valuable tool in optimizing the placement of the BLE beacons for the IPS system in the lab.

6.2 SERIAL MONITOR OUTPUT

The serial monitor output of the IPS project provides valuable information about the scanning process. When none of the devices are detected, the serial monitor shows "Scanning..." indicating that the scanner is actively searching for devices. However, when the scanner is within range of any of the devices, the serial monitor displays the name of the respective lab, along with the date and time stamp. The serial monitor provides a real-time display of the scanning process, making it easy to determine which labs are currently in range and accessible.



```

rst:0x1 (POWERON_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
configsip: 0, SPIWP:0xee
clk_drv:0x00,q_drv:0x00,d_drv:0x00,cs0_drv:0x00,hd_drv:0x00,wp_drv:0x00
mode:DIO, clock div:1
load:0x3fff0030,len:1184
load:0x40078000,len:12804
ho 0 tail 12 room 4
load:0x40080400,len:3032
entry 0x400805e4
Scanning...
MICROPROCESSOR AND MICROCONTROLLER LAB
MICROPROCESSOR AND MICROCONTROLLER LAB
MICROPROCESSOR AND MICROCONTROLLER LAB
ELECTRONICS CIRCUIT LAB
ELECTRONICS CIRCUIT LAB
ELECTRONICS CIRCUIT LAB

```

Fig 6.2: Output of the Serial Monitor

In Fig. 6.2, the serial monitor output is displayed, showcasing the lab names detected by the scanner. The output in the serial monitor is essential for tracking the scanner's progress and ensuring that the scanner is functioning as intended. The serial monitor also provides a record of which labs have been accessed and when, making it a valuable tool for monitoring the usage of the labs. By analyzing the serial monitor output, it is possible to identify any issues or inconsistencies in the scanning process and take corrective action as needed.

6.3 WEB HOSTING

The website that was created for this project contains information about the three labs in the university, including details about the lab facilities, equipment, and experiments that are conducted. Each lab has its own page on the website, which includes a brief introduction and a list of experiments with a short description and a YouTube link for each experiment. The website also includes contact information for the lab staff, such as their email addresses and office hours. Overall, the website serves as a valuable resource for students and faculty members who are interested in learning more about the labs and the work that is being done in them.

In order to host the website, the GitHub repository was utilized, which allowed for easy access and updating of the website content. The website was created using HTML, CSS, and JavaScript, and was designed to be responsive and user-friendly.

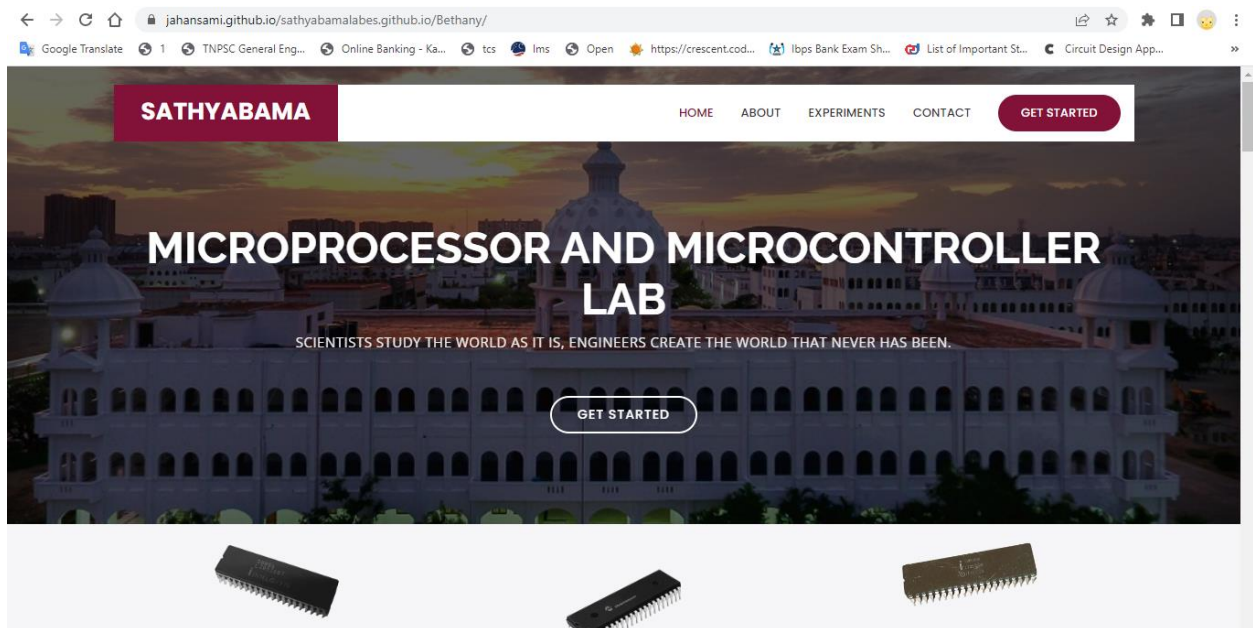


Fig 6.3: Screenshot of Microprocessor and Microcontroller Lab

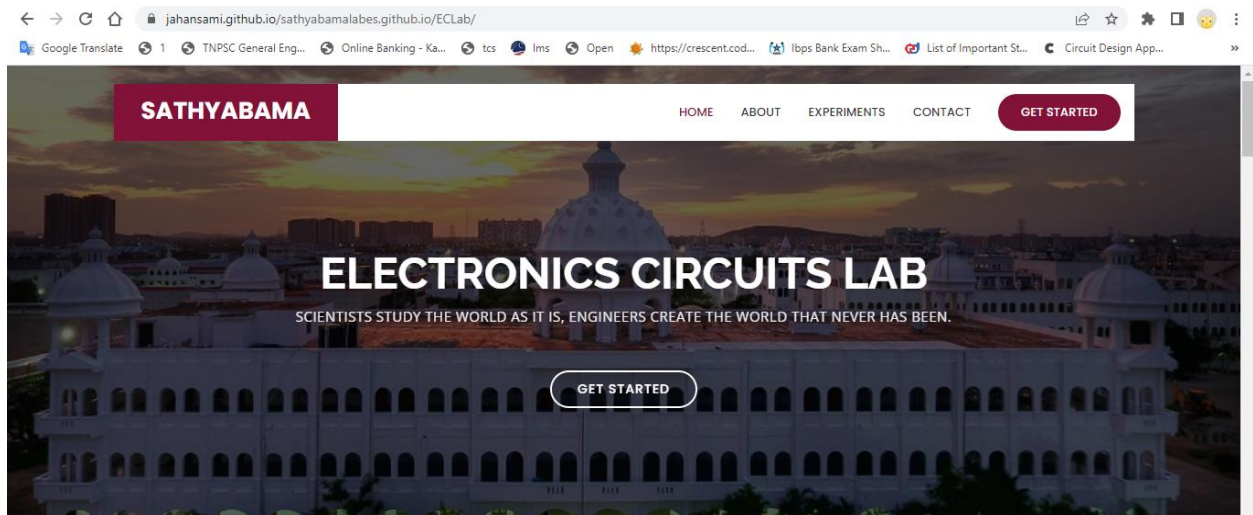


Fig 6.4: Screenshot of Electronics Circuits Lab

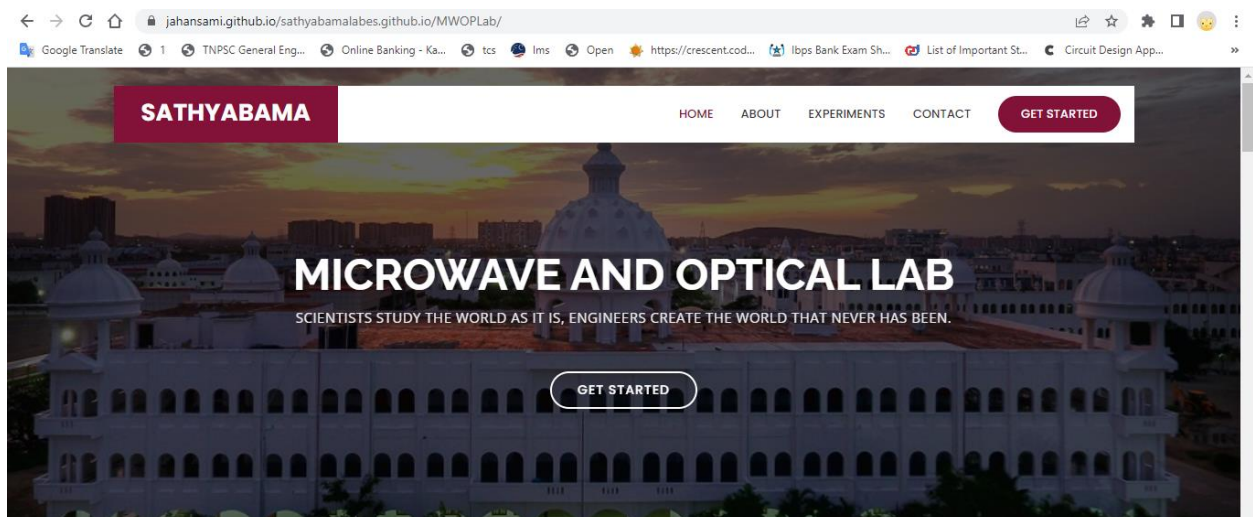


Fig 6.5: Screenshot of Microwave and Optical lab

To provide a visual representation of the website, screenshots of the website for three different labs have been included. These images are labeled as fig 6.3, fig 6.4, and fig 6.5. Hosting the website using the GitHub repository has made it easy to make updates and changes to the website without any hassle. Overall, the website has been a successful addition to this project, providing an efficient way to access the lab information and experiments.

6.4 PROPOSED OUTPUTS

The proposed output of our IPS system is a user-friendly and efficient way for visitors to access information about the labs in our department. As shown in Figure

6.6, when a visitor scans the QR code using our IPS system, it leads them directly to the lab website. The website contains information about the lab, experiments conducted in the lab, contact details of the lab staff, and other relevant information. Additionally, the website also includes a YouTube link for each experiment conducted in the lab, providing visitors with an interactive and immersive experience.

To provide a more personalized experience for visitors, we have designed a separate webpage for each lab in our department.

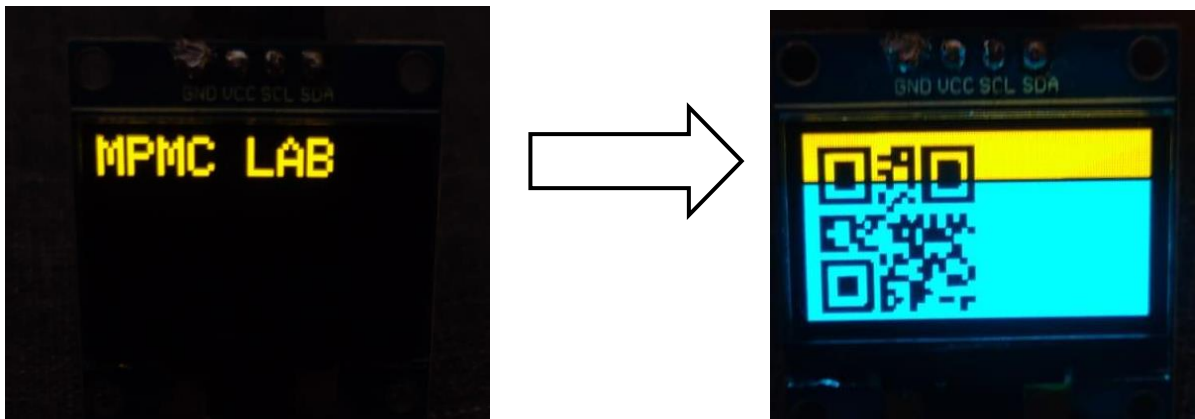


Fig 6.6 Image of QR code and MPMC Lab name

Figure 6.7 shows the website for the Microprocessor and Microcontroller Lab, which includes details about the lab, experiments, and contact information specific to that lab.

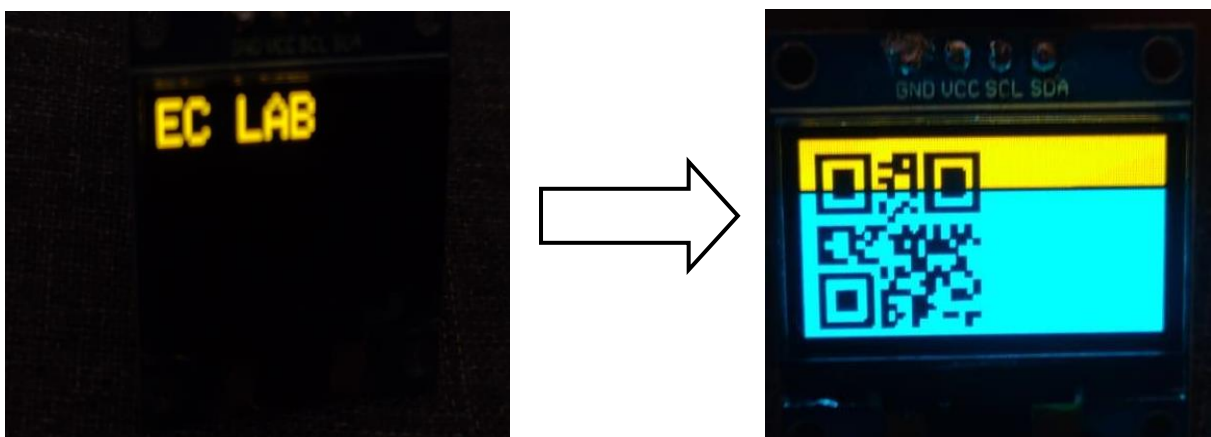


Fig 6.7 Image of QR code and Electronics Circuits Lab name

Similarly, Figure 6.7 shows the website for the Electronics Circuits Lab, Provide detailed information about the Electronics Circuits lab.

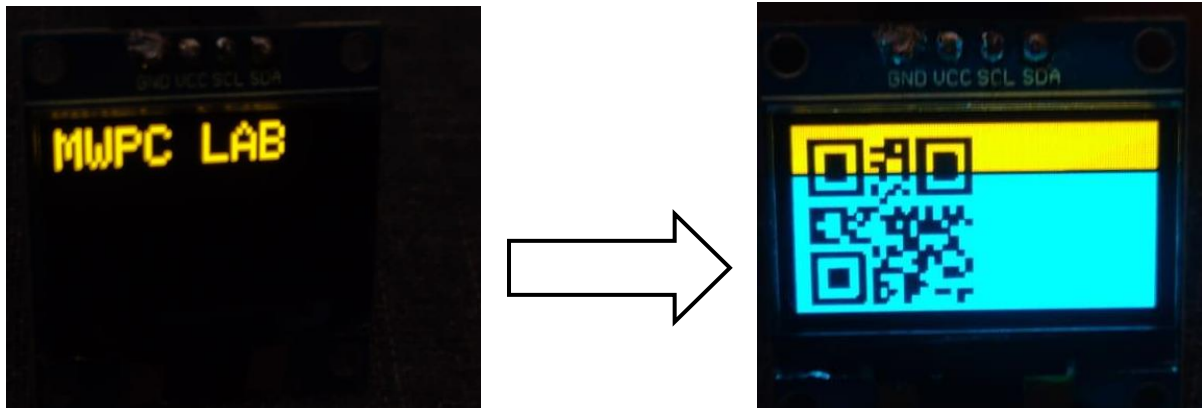


Fig 6.8 Image of QR Code and Microwave and Optical Lab name

Figure 6.8 shows the website for the Microwave and Optical Lab. Each website provides detailed information about the respective labs, making it easier for visitors to find what they are looking for.

Furthermore, we have hosted the website on GitHub, making it accessible to anyone with an internet connection. This ensures that visitors can access the information even after leaving the department premises. Overall, the proposed output of our IPS system, as demonstrated by the website, is a useful tool for both visitors and staff members in our department, providing quick and easy access to relevant information about our labs.

CHAPTER – 7

CONCLUSION

This chapter summarizes the whole project and its significance. Any future improvisations to the project are also suggested here. Suitable concluding remarks are provided.

7.1 CONCLUSION

In conclusion, the indoor positioning system project using ESP32 as a beacon has been successfully implemented and was able to determine the location of a person in a lab. The system has great potential to be useful in various scenarios where indoor navigation is required, such as in hospitals, museums, and shopping malls. The project also provided a valuable learning experience, allowing me to develop my skills in software development, hardware implementation, and data analysis.

However, the project has some limitations that need to be addressed, such as the need for calibration of the beacons and the optimization of the algorithms for better accuracy. Additionally, a user-friendly interface for displaying the lab information can be developed to enhance the user experience. Despite these limitations, the project has shown that an indoor positioning system using ESP32 as a beacon is feasible and can be implemented with the right skills and resources.

Overall, the project has provided valuable insights into the world of indoor positioning systems and has shown the potential for further development and improvement. The skills and knowledge gained through the project can be applied in future projects and will be useful in the pursuit of technological advancement.

7.2 FUTURE SCOPE

- The system can be integrated with mobile devices to provide a more user-friendly interface for displaying the lab information.
- The algorithms used in the indoor positioning system can be optimized to improve accuracy and reduce the error margin.
- The system can be expanded to cover larger areas or multiple buildings, and can be integrated with other systems such as security systems, HVAC systems, or lighting systems.

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