



Development of an Integrated IoT System for Remote Monitoring and Enhanced Safety Assurance in Outdoor Environments

D. S. D. M. D. Dawlagala
(Reg. No.: MS23006416)

A THESIS
SUBMITTED TO
SRI LANKA INSTITUTE OF INFORMATION TECHNOLOGY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE IN INFORMATION TECHNOLOGY
(ENTERPRISE APPLICATIONS DEVELOPMENT)

December 2024

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Dr Dilshan De Silva

Approved for MSc. Research Project:

MSc. Programme Co-ordinator, SLIIT

Approved for MSc:

Head of Graduate Studies, FoC, SLIIT

DECLARATION

This is to certify that the work is entirely my own and not of any other person, unless explicitly acknowledged (including citation of published and unpublished sources). The work has not previously been submitted in any form to the Sri Lanka Institute of Information Technology or to any other institution for assessment for any other purpose.

Sign:

D. S. D. M. D. Dawlagala

Date:2025-12-14.....

ABSTRACT

Development of an Integrated IoT System for Remote Monitoring and Enhanced Safety Assurance in Outdoor Environments

D. S. D. M. D. Dawlagala

MSc. in Information Technology (EAD)

Supervisor: Dr Dilshan De Silva

December 2024

Making places safer outside for freely operating has also risen in priority especially in places with little or no communication facilities and people can go out for camping and hiking. In this study, a distributed Internet of Things (IoT) system incorporating geofencing, environmental monitoring and real-time positioning system to improve outdoor navigation and safety has been developed and tested. The system includes one main hub and a number of sub devices connected to ESP32 microcontroller and LoRa 433 MHz for communication in addition to GPS (Neo-7M) for position location purposes. Linear and angular displacement measurements and their data processing and recording were performed using sub-devices that incorporated GPS and other modules used for receiving and transmitting data over a LoRa network. Sub and the main devices demonstrated data on 0.96 inches OLED both devices which enable users to receive up to date responses. There is also a type of geofencing action in the system, where an alert is sent when a sub-device departs an area that has been defined. The geofencing alerts can be managed through a web dashboard that utilizes Node.js, Next.js, and Web-Sockets for dashboard and main hub interaction. The main hub was also able to send and receive updates from the internet and then transmit this information to the sub-devices over the LoRa network thus bridging the gap that existed between local and remote operation. From the initial results, the newly proposed system is able to provide secure communication, precise location coordinates and prompt geofencing alerts even in outdoor environments with poor network support. The subsequent steps will seek to enhance the energy consumption of the system, improve communication coverage, and make more tests in real-life scenarios to assess the system as a whole.

ACKNOWLEDGEMENT

I owe a debt of gratitude to Dr. Dilshan De Silva, who has been a constant source of direction and feedback, as well as encouragement throughout this research work. He played an important role in my project in many aspects of IoT systems, GPS tracking and wireless technologies and his guidance has kept me motivated throughout the work.

Furthermore, I would like to thank the broader community of IoT researchers, developers, and open-source contributors whose knowledge and resources greatly enriched this project. Their work laid the foundation for the development of real-time monitoring and low-power wireless communication, and their willingness to share insights has truly demonstrated the spirit of collective growth in this field.

Lastly, I am deeply grateful to my peers, friends, and family for their unwavering support, patience, and understanding throughout this journey. Their belief in my work and their constant motivation helped me push through the complexities and challenges of this research.

TABLE OF CONTENTS

DECLARATION	i
ABSTRACT	ii
ACKNOWLEDGEMENT	iii
TABLE OF CONTENTS	iv
List of Figures	vii
List of Tables	viii
Chapter 1 Introduction	1
1.1 Background	1
1.2 Motivation	3
1.3 Problem Statement	9
1.4 Objectives	11
Chapter 2 Literature Review	16
2.1. Overview of Existing Research	16
2.2 Analysis of Gaps	20
2.3 Related Technologies	24
Chapter 3 Methodology	29
3.1 System Design	29
3.1.1 System Diagram	29
3.1.2 System Flow Diagram	31
3.1.3 Hardware and Software	32
3.1.4 Communication Protocol	35
3.1.5 Advantages of LoRa	36
3.1.6 Protocol Objectives	36
3.1.7 LoRa Module Configuration	38
3.1.8 Geofencing Mechanism	39
3.1.9 Geofence Creation	39

3.1.10 Web Dashboard for Push Geofence	39
3.1.11 Geofence Crossing Detection.....	40
3.1.12 System Integration and User Experience	41
3.1.13 Challenges and Considerations	42
3.1.14 Importance of Real-Time Visualization.....	42
3.2 Core Technologies Utilized	43
3.2.1 Node.js	43
3.2.2 Next.js	44
3.2.3 WebSocket	44
3.2.4 Node.js Back-End Development.....	45
3.2.5 Server Configuration.....	45
3.2.6 Front-End Development.....	46
3.2.7 Integration with WebSocket.....	47
3.2.7 Integration with MQTT server.....	47
Chapter 4 Results and Discussion.....	48
4.1 GPS Location Acquisition	48
4.2 GPS Performance Assessment.....	49
4.3 Implications for System Design.....	50
4.4 System Configuration and Mechanism	51
4.5 LoRa Communication Range Test Results	52
4.6 Observations from Range Tests	52
4.7 Challenges and Considerations	53
4.8 Implications for Future Development.....	54
4.9 OLED Display Integration.....	55
4.9.1 Functionality and User Interface.....	55
4.9.2 User Interface and Usability	56
4.10 OLED Display Performance in Varied Conditions.....	56
4.11 Geofencing Performance and Alerts	57
4.12 Web Dashboard Responsiveness and Real-time Data Display	58

Chapter 5 Future Enhancements	62
Chapter 6 Conclusion and Recommendations	64
6.1 Conclusion	64
6.2 Recommendations.....	65
References.....	68

List of Figures

Figure 3.1 System Architecture	29
Figure 3.2 Hub Module.....	30
Figure 3.3 Receiver Module (main).....	30
Figure 3.4 system flow chart.....	31
Figure 3.5 Web Dashboard	35

List of Tables

Table 4.1 GPS Accuracy Final Results	49
Table 4.2 LoRa Communication Range Test Results	52
Table 4.3 OLED Display Performance	56