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Design and Implementation of a Smart Campus Private Communication Network Using LoRa and ESP32

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Abstract - *Communication is essential in educational institutions, where students, faculty members, and administrative departments regularly exchange information. Most existing communication methods rely on internet services and public cellular networks. However, communication can become difficult during internet outages, network congestion, or emergency situations. To address this issue, this paper presents the design and development of a Smart Campus Private Communication Network using Long Range (LoRa) wireless technology and ESP32 microcontrollers. The proposed system is designed to enable communication between multiple devices without depending on an internet connection. Each communication device consists of an ESP32 microcontroller integrated with a LoRa transceiver module. A keypad-based interface is used to enter messages, while a display module is intended to show received information. The current prototype consists of three ESP32-based LoRa devices, and wireless communication between these devices has been established. The system is intended to support direct messaging and emergency broadcasting within a campus environment. Further development is required to improve message handling, implement broadcast communication, and explore multi-hop networking. Performance parameters such as communication range, transmission delay, packet delivery ratio, and power consumption are yet to be evaluated experimentally. The developed prototype serves as a starting point for building an independent and low-cost wireless communication network for educational institutions and other locations where conventional communication services may be unavailable.*

Key Words: LoRa, ESP32, Private Communication Network, Wireless Communication, Smart Campus, Offline Messaging, Embedded Systems

1. INTRODUCTION

Communication is an important part of everyday activities in educational institutions. Students, faculty members, and administrative departments need a convenient way to exchange information and coordinate their activities. Most institutions currently depend on internet connectivity, Wi-Fi, and mobile networks for communication. Although these services are widely used, they may become unreliable or unavailable during network failures and emergency situations.

One possible solution is to establish a separate wireless communication network that does not depend on external internet services. Long Range (LoRa) technology is suitable for this purpose because it supports long-distance wireless communication with relatively low power consumption.

In this project, an ESP32 microcontroller is combined with a LoRa transceiver module to develop a private communication network for campus applications. Multiple devices can exchange information wirelessly without requiring an internet connection. The main aim is to provide an alternative communication method that can be useful for campus coordination and emergency information sharing

1.1 Problem Statement

The existing comms in the schools are all reliant on the external internet and cellular networks. A network outage can obviously impact comms and delay the flow of vital information. There therefore needs to be an independent wireless comms system in place to allow for reliable internal comms without being reliant on the public networks.

1.2 Objectives

- To build three communication nodes using ESP32 boards and LoRa modules.
- To let users type and read text messages through a 4×4 keypad and an OLED display.
- To forward messages automatically through an intermediate node.
- To show a message travelling from source to destination via a relay node.
- To assess range, packet delivery, signal quality, latency, and power consumption.

2. RELATED WORK

Prior work relevant to this system falls into three groups. The first covers LoRa itself, a long-range, low-power radio technology whose behaviour has been studied in general terms [7], in building environments [6], and in a campus-

deployed low-duty-cycle IoT network [5]. The second concerns the ESP32, a microcontroller with built-in wireless capability that is commonly used as the processing element in IoT nodes [8]. The third covers multi-hop and mesh operation over LoRa, where intermediate nodes extend coverage beyond a single link; examples include a LoRa mesh network for peer-to-peer communication [1], multi-hop communication between LoRa nodes [2], a routing protocol designed for LoRa meshes [4], and a survey of multi-hop and mesh approaches [3]. Building on these areas, the present work combines ESP32 controllers with LoRa modules to provide text messaging between three nodes, with a middle node relaying traffic toward the destination.

3. PROPOSED SYSTEM

The system is made up of three wireless nodes. At each one, an ESP32 microcontroller handles message processing and communication, a LoRa module does the radio transmission, and an OLED display with a 4×4 keypad lets the user compose and read text messages. Suppose Node 1 sends a message to Node 3. If Node 3 is within range, the packet goes straight to it. If not, Node 2 receives the packet and forwards it to Node 3 automatically. Node 3 then displays the message, so the two end nodes can communicate through the intermediate relay.

4. IMPLEMENTATION METHODOLOGY

The prototype is made of three assembled hardware nodes. At each node the ESP32 is the controller, the LoRa module sends and receives packets, the OLED display shows output, and the 4×4 keypad takes input. The firmware ties these together by handling message entry, packet handling, destination identification, reception, and relay forwarding.

- **Hardware integration:** The ESP32, LoRa module, OLED display, keypad, and power supply are wired together at each node.
- **User interface:** Text is entered on the keypad, and messages and status information appear on the OLED.
- **Wireless communication:** Both LoRa modules use matching radio parameters, and the firmware handles packet transmission and reception.

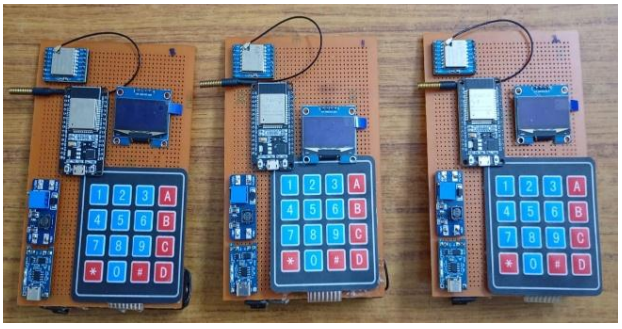


Fig -1: Hardware Integration of Proposed Smart Campus Private Communication Network.

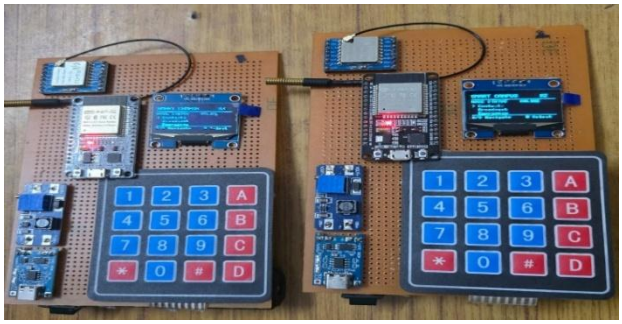


Fig -2: Hardware Implementation Demonstrating Wireless Communication Between Two ESP32-Based Nodes.

- **Relay operation:** The intermediate node recognises packets meant for another node and retransmits them toward the destination without user involvement.
- **System verification:** Direct communication and the Node 1 → Node 2 → Node 3 relay path are tested while noting the test conditions and observed outputs.

5. RESULTS AND DISCUSSION

The prototype comprises three wireless nodes, each built around an ESP32 and a LoRa module. At every node, text messages are entered and displayed using a 4×4 keypad and an OLED screen. Nodes can communicate with one another, and when Node 3 cannot be reached directly from Node 1, Node 2 acts as the relay. It receives the packet and forwards it automatically toward the destination, so communication still works where the direct source-to-destination link does not.

This demonstrates the basic operation of relay-based communication for a campus setting. Detailed experimental results (communication range, packet delivery rate, received signal strength, end-to-end latency, and power consumption) have not yet been documented, so no numerical performance claims are made at this stage.

A complete experimental evaluation would cover the following:

- Direct communication range between two nodes.
- Communication range when the intermediate node relays the message.
- Packet delivery rate and received signal quality at varying distances.
- End-to-end message latency.
- Battery operating time of each node.

6. CONCLUSION

This paper presented a relay-based wireless communication system, the Smart Campus Private Communication Network, built from ESP32 microcontrollers and LoRa modules. In its three-node

design, an intermediate node forwards packets automatically whenever the source and destination cannot reach each other directly, and OLED displays with 4×4 keypads provide a simple way to write and read messages. The prototype shows that LoRa relay communication is a feasible way to extend connectivity across a campus. Future work will measure communication range, packet delivery reliability, latency, and power consumption under varying conditions. With those results, the system could be developed into a dependable private communication option for areas with limited conventional network coverage.

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