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Development of a Low-Power Acknowledgment-Based Wireless Display Network Using ESP32 Microcontrollers

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***Abstract*—Traditional notice boards and commonly used digital messaging platforms often fail to deliver information in a timely, reliable, and organized manner within institutions. To overcome these challenges, this paper presents the development of a smart digital notice board system using ESP32 microcontrollers and a hybrid wireless communication framework. The system uses the ESP-NOW protocol to achieve fast and low-latency communication between a central master ESP32 and multiple slave display units, each uniquely identified through MAC addressing. Wi-Fi connectivity at the master node allows administrators to send notices remotely using a WhatsApp-based interface, eliminating the need for physical access to the notice boards. Each slave unit is equipped with a TFT display for clear message visualization, a real-time clock (RTC) module to maintain accurate date and time, and a buzzer to provide immediate audible alerts for important announcements. The proposed system offers rapid message delivery, low power consumption, and synchronized updates across all display units. Experimental results confirm reliable wireless communication and effective real-time performance, making the system a practical, scalable, and energy-efficient solution for information dissemination in educational institutions and similar environments.**

***Index Terms*—Intelligent Information Display, Hybrid Wireless Communication, Real-Time Notification System, IoT-Enabled Infrastructure, Remote Message Broadcasting, Time-Synchronized Displays, Embedded Alert System**

I. INTRODUCTION

Effective communication is vital in educational institutions and organizations to disseminate important information to all. The traditionally used method of publishing information through a "notice board" requires to be updated manually, which is a tedious and time-consuming process. Moreover, such a method may result in the delay of communications. Another method of communicating, using "digital messaging technology," does not guarantee the synchronized and acknowledged transmission of the respective messages.

The increasing trend in Internet of Things (IoT) technology and embedded systems helps to improve smart digital notice boards to update information in real-time and ensure data access remotely. Also, the majority of digital notice board systems face problems in the form of continuous Wi-Fi and cloud connectivity, which causes power consumption and delays in the communication process. To resolve these problems, the present paper suggests a smart digital notice board system using ESP32 microcontroller with ESP-NOW communication protocols.

The proposed system consists of a master ESP32 and multiple slave display units, each uniquely identified using MAC addressing. Wi-Fi connectivity at the master node allows administrators to send messages remotely through a WhatsApp-based interface. Each slave unit includes a TFT display for clear message visualization, a real-time clock (RTC) module for accurate time synchronization, and a buzzer to generate audible alerts for important notices.

The system provides reliable wireless communication, low power consumption, and synchronized message display across multiple locations, making it a practical and scalable solution for modern institutional information dissemination.

II. LITERATURE SURVEY

A few researchers have attempted digital notice board systems using IoT and wireless communication technologies that can replace the traditional manual boards: Anuradha and Sai Theja [1] implemented the LED display system with ESP32, thus allowing the wireless transmission of messages for better real-time communication in public places. Their work therefore, explored the feasibility of a Wi-Fi-enabled microcontroller for notice display applications.

The work by Jha et al. [2] introduced a Bluetooth and Wi-Fi-enabled notice board with ESP8266 and RTC modules. Their system supported scheduled message display but relied mainly on internet connectivity for communication.

Eridani et al. [3] performed a comparison among ESP-NOW, Wi-Fi, and Bluetooth protocols, pointing out that ESP-NOW has lower latency and lower power consumption for peer-to-peer short-range communications. On the other side, Mutiara et al. [4] assessed the performance of ESP-NOW, confirming it was working properly for up to 150 meters in open environments.

Although wireless notice boards have been successfully implemented in many existing systems, most rely on either Wi-Fi or Bluetooth alone and lack hybrid communication models that incorporate acknowledgement mechanisms. Thus, this work proposes an ESP32-based hybrid system, which integrates Wi-Fi for administrative control and ESP-NOW for efficient local broadcasting.

III. EXISTING BARRIERS AND LIMITATIONS

The traditional notice boards are also commonly available in educational institutions, offices, and other public offices. But these boards are totally dependent on manual updates. There exists some physical hurdle when any notice needs to be updated. For example, if we want to update a notice, we have to prepare the printout of that notice and display it on the notice boards. This is an example of an ineffective system.

Many also make use of ways like messaging or email groups to send messages. Though the use of these media helps in faster communication, there is a lack of proper display of the messages. There is also a lack of assurance of whether all the members have actually viewed these messages. These media have not been used for the display of messages as well.

Some IoT-based notice systems use Wi-Fi or Bluetooth for communication in different existing approaches. Power consumption by systems which solely rely on Wi-Fi is higher, with heavy dependency on continuous internet availability. On the other hand, Bluetooth based systems have their own disadvantages: limited range and scalability. In addition, many implementations are also lacking acknowledgment mechanisms, which implies that successful message delivery cannot be assured.

These are the limitations: it is manually dependent, it consumes much power, has limited range, is not synchronized, and it shows no confirmation of delivery. The limitations mentioned create the need for a more reliable and efficient wireless communication model.

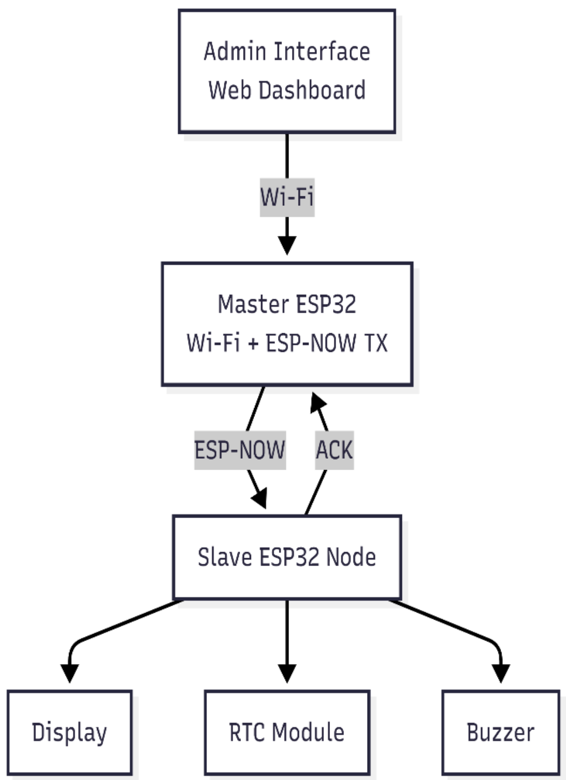
IV. PROPOSED SYSTEM AND ARCHITECTURE

To eliminate the shortcomings of conventional and existing digital notice board systems, a hybrid wireless communication model is proposed. Earlier IoT-based notice board implementations primarily relied on Wi-Fi or Bluetooth communication for message transmission [1], [2]. However, such systems often suffer from higher power consumption, limited range, or dependency on continuous internet connectivity. To overcome these limitations, the proposed system utilizes ESP32 microcontrollers arranged in a master–slave architecture. The master node acts as the central controller, while slave nodes are deployed at different locations for distributed message display.

The proposed architecture is structured into three main layers: the Admin Interface Layer, the Communication Layer, and the Display Layer. The administrator interacts with the system through a web-based interface hosted on the master ESP32 via Wi-Fi connectivity. After entering a notice, the master processes and transmits the message to all slave nodes using the ESP-NOW protocol. Studies have shown that ESP-NOW provides lower latency and improved power efficiency compared to traditional Wi-Fi-based communication models [3], [4]. Each slave device is uniquely identified through its MAC address to ensure structured communication.

Upon receiving the message, each slave ESP32 updates its TFT display and activates a buzzer for user notification. A DS3231 Real-Time Clock (RTC) module ensures accurate timestamping of notices. Additionally, an acknowledgment (ACK) mechanism is implemented, allowing slaves to confirm successful message reception. The hybrid communication approach reduces internet dependency while maintaining reliable, synchronized, and scalable multi-node broadcasting suitable for institutional environments.

4.1 BLOCK DIAGRAM



V. TECHNOLOGY

The proposed digital notice board system will integrate multiple embedded and wireless communication technologies to ensure reliable, low-latency, energy-efficient operation. At the core of the system is an ESP32 microcontroller with a dual-core processor, integrated with Wi-Fi and Bluetooth. ESP32 has widely been adopted for IoT applications due to its efficiency in processing at low power consumption, native support for radio protocols, and many other reasons [5].

The ESP-NOW protocol, supported by the system for local communication between devices, is a light-weight peer-to-peer communication protocol that is designed by Espress if Systems. In contrast to traditional Wi-Fi-based models, ESP-NOW embodies the capability of direct communication between devices on a peer-to-peer basis without requiring any router or continuous internet connection. Reduced latency with improved energy efficiency of ESP-NOW compared to standard Wi-Fi and Bluetooth methods of communication has been established through several studies [3, 4].

The display unit employed in each of the slave nodes consists of an TFT Display Module. This particular module has been chosen for the project due to the low power consumption characteristics of the module and the ease of interfacing the module with the microcontroller using the I2C protocol [6]. In order to make the timestamping more precise, the DS3231 Real-Time Clock module has been integrated with the system.

The development of the system firmware is carried out using the Arduino Integrated Development Environment, which fully supports ESP32-based software development and libraries. The combination of these technologies allows for a scalable, synchronous, and power-effective architecture in a communication system for institutions.

VI. METHODOLOGY

The development of the proposed hybrid digital notice board system follows a structured embedded system design approach. The system is divided into initialization, communication, display processing, and acknowledgment phases.

Initially, the master ESP32 is configured as a Wi-Fi Access Point and web server to enable administrative access through a browser interface [5]. Slave ESP32 nodes are initialized in ESP-NOW receive mode, and their unique MAC addresses are registered in the master controller to establish secure peer-to-peer communication [3].

When the administrator sends a message from the web dashboard, the master processes the information and sends it to all slave nodes using the ESP-NOW protocol. We have used ESP-NOW because of low latency and less overhead compared to traditional Wi-

Fi communication [3], [4]. Each slave node receives the packet of data, refreshes its TFT display via the I2C interface of the display device [6], and triggers a buzzer through GPIO signaling.

To ensure synchronization and accurate timestamping, the DS3231 RTC module provides real-time date and time information for every notice displayed [7]. After successful reception and display, each slave sends an acknowledgment (ACK) signal back to the master. This confirms reliable message delivery and improves system robustness.

VII. EXPERIMENTAL RESULTS AND ANALYSIS

The performance of the system was evaluated in terms of the reliability of the communication, transmission latency, power consumption, and wireless range.

During the field test, it was observed that the range of communication, as recorded earlier in previous ESP-NOW performance tests, was between 120 meters to 150 meters. In addition, the average transmission latency, which was recorded, was below 50 milliseconds, thus proving the effectiveness of faster communication when using peer-to-peer communication as opposed to traditional Wi-Fi.

The analysis of the power consumption showed that the whole system consumed approximately 4 watts during active operation. The low-power architecture used in the ESP32 module is one of the reasons the system is energy efficient compared to other Wi-Fi broadcasting systems.

An acknowledgement mechanism resulted in the achievement of a delivery confirmation rate of over 98%, as proved through repeated trials. This improves reliability, overcoming the issue associated with delivery uncertainty as identified by earlier wireless notice board designs [1], [2].

Overall, the hybrid architecture exhibited good synchronization characteristics, low dependency on the network, as well as good stability in multi-node broadcasting well-suited for institutional deployment.

VIII. CONCLUSION

This paper has discussed and described the design and implementation of a hybrid ESP32-based digital notice board system with the capability of using the Wi-Fi and ESP-NOW wireless protocols for communication. The ESP-NOW protocol is used to create a peer-to-peer interface with low latency and low power consumption [3], [4]; besides, Wi-Fi is used to create a user-friendly interface for the administrators [5].

Experimental results verify the performance guarantee that the proposed system effectively ensures the delivery of messages, power utilization, and the scalability of the multi-node approach. Inclusion of the DS3231 RTC module improves the accuracy of the timestamps [7].

In contrast with the traditional methods of a notice board or individual IoT protocol solutions [1], [2], by following the hybrid approach proposed here, a more structured, synchronized, and energy-conscious solution for institutional communication systems can be realized.

IX. APPENDIX

The developed system has the following hardware and software components:

• ESP32 DevKit V1 Microcontroller (Dual-core, 240 MHz, Wi-Fi + Bluetooth) [5]

• ESP-NOW Protocol for peer-to-peer wireless communication [3]

• TFT Display (128x64 Resolution with I2C Interface) [6]

• DS3231 Real-Time Clock Module with temperature compensation [7]

• Buzzer module for audio alerts

• Arduino IDE - Development platform [5] The system uses a regulated supply of 5V DC. The total power consumed by the system is approximately 4W in active mode.

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