Smarttalk Clock: An Assistive Time Announcement System

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How to Cite this Article:

Singh, A., Bhurtiya, R., Mitra, A., Yadav, A. & Shrivastava, R. (2026). Smarttalk Clock: An Assistive Time Announcement System. International Journal of Creative and Open Research in Engineering and Management, 02(03). https://doi.org/10.55041/ijcope.v2i3.091

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Abstract **-** This paper presents the design, development, and performance evaluation of a Talking Clock—a real-time embedded system capable of displaying and audibly announcing the current time AbstractTime announcement and public address systems are essential components in educational institutions, healthcare facilities, and public infrastructures. Conventional digital clocks provide only visual representation of time and lack the ability to communicate information dynamically. Talking clocks overcome this limitation by providing audio-based time announcements, but most existing systems are limited to fixed functionality and cannot adapt to real-time announcement requirements.

This paper presents the design and implementation of a dynamic microcontroller-based talking clock and smart announcement system using the ESP32 microcontroller, DS3231 Real-Time Clock (RTC), DFPlayer Mini audio module, LED matrix display, and a push-button interface. The system announces the current time on demand and is further enhanced to support dynamic and real-time announcements through wireless communication. The proposed system can temporarily override the regular clock operation to broadcast emergency or scheduled announcements, making it suitable for smart classrooms, hospitals, and public alert systems. The design emphasizes accuracy, flexibility, scalability, and low-cost implementation.

Introduction

Accurate timekeeping and effective information dissemination are critical in modern society. Digital clocks are widely used for displaying time; however, they depend entirely on visual perception, which limits their usefulness for visually impaired individuals and in situations where visual attention is not possible. Talking clocks were introduced to address this issue by providing audible time announcements.

Despite their usefulness, conventional talking clocks suffer from several limitations. They are typically designed for a single function—announcing time—and lack the ability to adapt to changing requirements such as emergency alerts or public announcements. With the rapid advancement of embedded systems and Internet of Things (IoT) technologies, there is an increasing demand for intelligent devices capable of delivering **dynamic, real-time information**.

The ESP32 microcontroller offers integrated Wi-Fi and Bluetooth capabilities, making it an ideal choice for developing smart and connected systems. This paper proposes a **dynamic talking clock and smart announcement system** that combines accurate timekeeping with real-time announcement functionality. The system is designed to be modular, cost-effective, and suitable for deployment in educational institutions, healthcare facilities, and public spaces.

II. Related Work

Several studies have explored talking clock systems and audio-based assistive devices. Early talking clocks were based on simple microcontrollers with pre-recorded voice modules and lacked flexibility. Some systems focused on assistive technologies for visually impaired users but did not support real-time updates or remote control.

Recent research has incorporated IoT-based public announcement systems using wireless communication; however, these systems often operate independently of timekeeping functions. The proposed system integrates both **time announcement and dynamic broadcasting** into a single embedded platform, offering greater versatility compared to existing solutions.

III. System Architecture

The overall system architecture is divided into **hardware architecture** and **software architecture**.

A. Hardware Architecture

The hardware components of the proposed system include:

1) ESP32 Microcontroller

The ESP32 serves as the central processing unit of the system. It manages time processing, audio playback control, LED matrix operation, and wireless communication. Its low power consumption and integrated connectivity make it suitable for IoT-based applications.

2) DS3231 Real-Time Clock (RTC)

The DS3231 RTC module provides high-precision timekeeping with temperature compensation. It communicates with the ESP32 using the I²C protocol and maintains accurate time even during power failures using a backup battery.

3) DFPlayer Mini Audio Module

The DFPlayer Mini is used for audio playback. It reads pre-recorded audio files stored on an SD card and outputs sound through a speaker. This module allows clear and reliable audio announcements.

4) LED Matrix Display

The LED matrix display is used to show the current time as well as announcement messages. It provides a visual complement to the audio output.

5) Push Button Interface

A push button allows the user to manually trigger time announcements. This interface ensures ease of use and accessibility.

IV. Software Design and Implementation

The software for the system is developed using an embedded programming environment compatible with the ESP32. The software architecture follows a modular design approach to ensure scalability and ease of maintenance.

A. RTC Handling

The ESP32 continuously reads time data from the DS3231 RTC module. The obtained data is formatted for both display and audio output.

B. Audio Control

The audio files corresponding to hours, minutes, and announcements are stored on the SD card. The ESP32 sends serial commands to the DFPlayer Mini to play the required audio files.

C. Display Management

The LED matrix is updated in real time to display the current time. During announcement mode, the display

temporarily shows the announcement message.

D. Wireless Communication

Wireless communication using Wi-Fi or Bluetooth enables dynamic announcement updates. When a new announcement is received, the system prioritizes it over the regular clock function.

V. Working Principle

The system operates in two primary modes:

A. Normal Clock Mode

In normal mode, the ESP32 reads the current time from the RTC and displays it on the LED matrix. When the user presses the push button, the system announces the current time through the speaker.

B. Announcement Mode

When an announcement command is received wirelessly, the system enters announcement mode. The regular clock operation is temporarily suspended, and the announcement is displayed and broadcast through audio. After completion, the system automatically returns to normal clock mode.

VI. Dynamic Announcement Mechanism

The dynamic announcement feature distinguishes the proposed system from conventional talking clocks. Announcements can be updated in real time without physical access to the device. A priority-based mechanism ensures that critical announcements override regular time announcements.

This feature is particularly useful in emergency situations, where timely and clear communication is essential.

VII. Applications

The proposed system can be deployed in various environments, including:

- Smart classrooms and educational institutions
- Hospitals and healthcare facilities
- Railway stations and public waiting areas
- Offices and industrial environments
- Assistive systems for visually impaired users

VIII. Advantages of the Proposed System

- Accurate and reliable timekeeping
- Real-timeand dynamic announcement capability
- Wireless connectivity for remote updates
- Low-cost and energy-efficient design
- Modular and scalable architecture

IX. Experimental Results and Discussion

The system was tested under multiple operating conditions. The DS3231 RTC demonstrated high accuracy over extended periods. Audio playback using the DFPlayer Mini was clear and distortion-free. The LED matrix displayed information correctly under both normal and announcement modes. The dynamic announcement feature showed minimal latency, confirming the effectiveness of the wireless communication mechanism.

X. Conclusion

This paper presented the design and implementation of a **dynamic microcontroller-based talking clock and smart announcement system** using ESP32. By integrating real-time announcement capabilities with a talking clock, the system addresses the limitations of traditional designs. The proposed solution is reliable, scalable, and suitable for a wide range of real-world applications.

Unlike conventional talking clocks that are limited to static operation, the proposed system introduces **real-time adaptability** through wireless communication. The ability to override regular clock functionality and broadcast instant announcements significantly enhances the usefulness of the system in real-world environments such as educational institutions, hospitals, and public spaces. The LED matrix display complements the audio output by providing visual information, improving accessibility for a broader range of users.

XI. Future Scope

Future enhancements may include:

Text-to-Speech (TTS) Integration

The current system relies on pre-recorded audio files. Future versions can integrate text-to-speech engines to convert dynamically received text into audio, eliminating the need for storing multiple voice files and enabling unlimited announcement customization.

Mobile Application Control

A dedicated mobile application can be developed to control announcements, schedule alerts, and monitor system status. This would improve user interaction and simplify remote management.

Multilingual Support

The system can be extended to support multiple languages, making it suitable for diverse regions and multilingual public environments.

Cloud-Based Scheduling and Logging

Integration with cloud platforms can enable scheduled announcements, historical data logging, and centralized

control of multiple devices deployed at different locations.

- **Voice Command Interface**

Voice recognition can be added to allow hands-free operation, enabling users to request time announcements or trigger alerts using voice commands.

- **Power Optimization and Backup**

Future designs may include low-power modes, solar power integration, and enhanced battery backup to ensure uninterrupted operation during power failures.

- **Security Enhancements**

Secure communication protocols and authentication mechanisms can be implemented to prevent unauthorized access or misuse of the announcement system.

- **Scalability for Smart Infrastructure**

The system can be expanded into a network of synchronized units for large-scale deployment in smart cities, railway stations, and industrial environments.

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