COAP Protocol based Smart Attendance System

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ABSTRACT

The **COAP Protocol-Based Smart Attendance System** is an innovative IoT solution designed to automate and streamline the attendance tracking process. By leveraging the Constrained Application Protocol (COAP) for lightweight communication, this system ensures efficient and real-time data transfer between devices. The system utilizes an ESP32 microcontroller integrated with Passive Infrared (PIR) and Infrared (IR) sensors to detect human presence and identify individuals, enabling accurate attendance marking with minimal manual intervention.

The PIR sensor detects motion, activating the system only when someone is present, which optimizes energy usage. The IR sensor further identifies individuals, ensuring precise user recognition. The data is processed by the ESP32 and transmitted securely using the COAP protocol to a central server or database for record-keeping.

This project holds significant potential for implementation in schools, offices, and industries, where traditional methods of attendance tracking are time-consuming and prone to errors. By automating the process, the system saves time, reduces human error, and ensures scalability for larger networks. Additionally, the use of COAP makes it a cost-effective and energy-efficient solution, suitable for resource-constrained IoT environments.

The smart attendance system not only demonstrates the practical application of IoT and COAP in daily life but also lays the foundation for further innovations in automated systems.

CONTENTS

1. Introduction

1.1. Objective

The aim of this project is to design and implement a smart attendance system that harnesses the power of IoT (Internet of Things) technology to streamline and automate the process of attendance recording. By utilizing advanced sensors to detect human presence and uniquely identify individuals, the system ensures high accuracy, reduces errors, and eliminates the need for extensive manual intervention.

1.2. Technology and Protocol

- **COAP Protocol**: The Constrained Application Protocol (COAP) is used to enable lightweight and efficient communication between devices. Its simplicity makes it ideal for IoT-based systems.
- **IoT Framework**: The system integrates sensors with a microcontroller (ESP32) to process data and transmit it using the COAP protocol.

1.3. Key Features of the System

- Detects human presence through motion sensing.
- Identifies individual users using IR sensors.
- Sends real-time attendance data to a central server or database.

1.4. Significance

This project highlights the application of IoT and COAP in creating cost-effective and scalable solutions for everyday challenges like attendance tracking. The system is designed to be lightweight, energy-efficient, and suitable for environments like schools, offices, or industrial setups.

2. Devices and Sensors Used

2.1. ESP32 Microcontroller

- Serves as the system's core processing unit.
- Features Wi-Fi and Bluetooth capabilities for seamless data transmission using the COAP protocol.
- Processes inputs from sensors and sends attendance data to the server.

2.2. PIR (Passive Infrared) Sensors

- Detects motion by sensing infrared radiation emitted by humans.
- Activates the system only when presence is detected, conserving energy.

2.3. IR (Infrared) Sensors

- Identifies individual users through unique reflective or transmitted infrared signals.
- Ensures accurate differentiation between users for precise attendance marking.

2.4. LED

- Used as a signal for entry/exit detection.
- Turns red during entry.
- Turns green during exit.

2.5. Laptop

- Used to write and upload the program code to the ESP32 using the Arduino IDE.
- Serves as a development and debugging platform for the system's code.

2.6. Breadboard

- Provides a solderless platform to assemble the circuit during prototyping.
- Connects the ESP32, sensors, and other components seamlessly.

2.7. Jumper Wires

- Used to interconnect components within the circuit.
- Enable quick modifications and a flexible setup.

3. System Design and Circuit Diagram

The COAP Protocol-based Smart Attendance System integrates sensors and a microcontroller to track attendance efficiently. The following points detail the system's design and circuit setup:

ESP32 Microcontroller:

The ESP32 acts as the central control unit, executing logic for detecting and counting entries and exits. It reads input signals from the IR and PIR sensors and processes these inputs to update the attendance count. Additionally, it communicates with a laptop via USB for programming and monitoring through the Arduino IDE.

IR Sensor:

Positioned inside the gate, the IR sensor detects obstructions in its line of sight. It outputs a HIGH signal when an object blocks its beam, confirming the presence of a person inside the gate. This sensor is critical for validating the completion of an entry or exit sequence.

PIR Sensor:

The PIR sensor detects motion within its range and triggers the start of an entry process. It also helps in confirming the exit process. It outputs a HIGH signal upon detecting movement, signalling the ESP32 to track the object's progression through the gate.

LED:

During entry, it turns red and during exit, the LED turns green.

Timing Mechanism and Logic:

The system uses a timeout mechanism of 3 seconds to ensure accuracy. If an entry or exit sequence is not completed within this period, the process is reset to prevent false counts. The logic implemented in the ESP32 ensures robust synchronization between the sensors, minimizing errors from overlapping or rapid movements.

Laptop Integration:

A laptop is used for programming the ESP32 and monitoring real-time attendance updates via the Serial Monitor. During testing and debugging, the laptop supplies power to the ESP32 through a USB connection. For standalone operation, an external power source can be used.

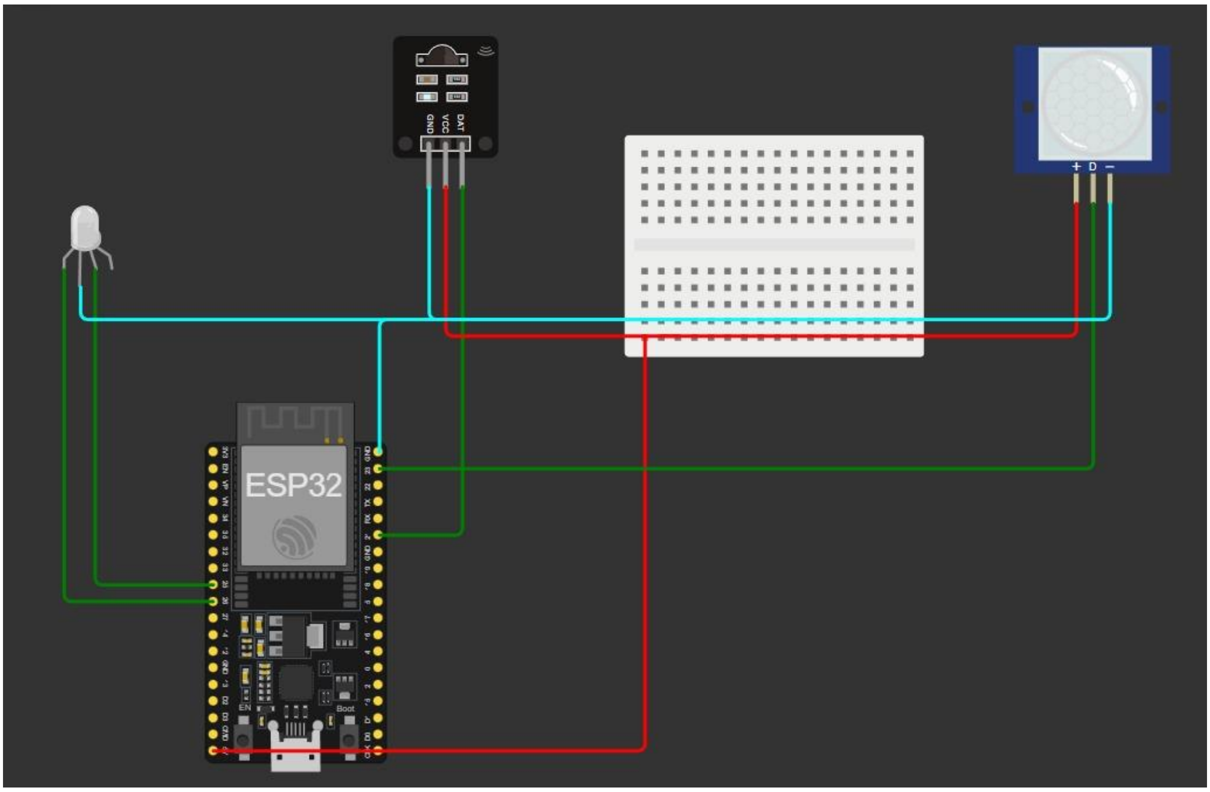
Circuit Connections:

The IR sensor is connected to GPIO 21 and the PIR sensor to GPIO 23 of the ESP32, both configured as input pins.

The ESP32 processes these digital signals to differentiate between valid and invalid entry/exit sequences.

The power supply for the ESP32 is provided via the USB connection during development.

Circuit Diagram:



Signal Flow:

When a person approaches the gate, the PIR sensor first detects motion and signals the ESP32 to start tracking. The IR sensor then confirms the person’s movement through the gate by detecting the obstruction. Based on the sequence of these sensor activations, the ESP32 increments or decrements the attendance count, ensuring precise tracking.

This integrated system design and circuit configuration provide a reliable solution for automating attendance tracking with minimal errors and robust performance.

4. Implementation Process

The implementation of the COAP Protocol-based Smart Attendance System involves setting up hardware components, writing Arduino IDE code, and testing the system to ensure accurate operation. Below is a detailed breakdown of the implementation process:

Hardware Setup:

- Connect the IR sensor to GPIO 21 of the ESP32 and the PIR sensor to GPIO 23. Both sensors are powered by the 3.3V and GND pins on the ESP32.
- Verify that the sensors are securely mounted and positioned correctly. The IR sensor is aligned to detect obstructions at the gate, while the PIR sensor is placed to sense motion within its range.

- Connect the ESP32 to the laptop via USB for programming and testing.

Code Development:

- The logic for detecting and differentiating between entries and exits is implemented using the Arduino IDE.
- State tracking variables (*entryDetected*, *exitDetected*) are used to monitor the progress of entry or exit events.
- A timeout mechanism ensures that incomplete sequences are reset after 3 seconds to avoid erroneous counts.
- The attendance count is displayed every 3 seconds through the Serial Monitor, providing real-time updates.

Testing and Debugging:

- The system was tested by simulating entry and exit scenarios to ensure correct incrementing and decrementing of the attendance count.
- Edge cases, such as incomplete sequences or simultaneous sensor activations, were handled by refining the code logic.
- Real-time monitoring through the Serial Monitor allowed for debugging and optimizing sensor responsiveness.

5. Integration of COAP Protocol

The Constrained Application Protocol (COAP) is a lightweight protocol designed for IoT devices, enabling communication between devices and remote servers. Integrating COAP into the Smart Attendance System adds the functionality of remote attendance logging and monitoring. Below is a detailed process for its integration:

CoAP Server Implementation:

A CoAP server was created using the coap library in Node.js, hosted on localhost:5683. The server listens for POST requests to update attendance data and GET requests to fetch this data. Attendance updates are logged with timestamps, and the data is stored in an array to maintain a historical record. The server also includes error handling for unsupported requests and returns appropriate responses based on the request type.

Client Data Transmission:

The client-side implementation utilizes a CoAP client script (client_send.js) to send random attendance data to the server. The script establishes a POST request to the CoAP server with attendance counts and processes the server's response. This script simulates real-time updates from IoT devices and validates server responses for debugging.

HTTP-COAP Bridge for Data Access:

An Express-based HTTP server was implemented to bridge the CoAP server with a web application. It uses the CoAP client to fetch attendance data via GET requests, parses the JSON response, and serves it through an HTTP API (/api/attendance). The cors middleware ensures that the data can be accessed securely from the front-end.

Web Application for Visualization:

A front-end script (script.js) fetches attendance data every two minutes from the HTTP API and dynamically updates two components: a log area displaying the last 10 attendance updates and a table summarizing daily maximum attendance. Data processing and display logic include sorting and filtering to enhance clarity, providing an intuitive user interface for attendance monitoring.

Integration of Local IP Detection:

The HTTP server dynamically detects and binds to the machine's local IP address using the os library. This ensures compatibility in various network environments and simplifies deployment across systems.

System Integration Workflow:

- IoT devices or simulations send attendance data to the CoAP server.
- The CoAP server stores and processes the data, making it available for retrieval.
- The HTTP server retrieves data from the CoAP server and serves it through an accessible API.
- The front-end fetches and visualizes the data, ensuring end-to-end integration for real-time monitoring.

6. Results and Conclusion

The system successfully tracked attendance by accurately detecting entries and exits using the IR and PIR sensors. The attendance count was updated in real time and displayed at regular intervals, ensuring correct tracking. The integration of the COAP protocol enabled remote monitoring, with data sent from the ESP32 to a server, confirming reliable communication and data logging. The system demonstrated stability with no significant delays in detecting events, and the timeout mechanism prevented false readings, enhancing overall reliability.

In conclusion, the COAP Protocol-based Smart Attendance System achieved its objective of providing an automated and efficient attendance tracking solution. The system effectively integrated sensors for accurate detection and utilized the COAP protocol for remote monitoring. It offers a scalable, resource-efficient solution for real-time attendance management, with potential for further expansion to include additional features such as notifications or centralized dashboards.

7. References

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