Intelligent Water Consumption Control Using IoT and AI

Problem Statement

Water scarcity is becoming a critical global issue due to population growth, climate change, and inefficient consumption. Conventional water meters are passive systems that only measure usage for billing purposes and fail to provide real-time monitoring, anomaly detection, or active control against leaks and excessive consumption.

Objectives

- Monitor water consumption in real time using IoT sensors
- Detect abnormal water usage and potential leaks using AI
- Actively control water flow through automated intervention
- Provide users with real-time visualization and historical analytics
- Reduce water waste and promote sustainable consumption

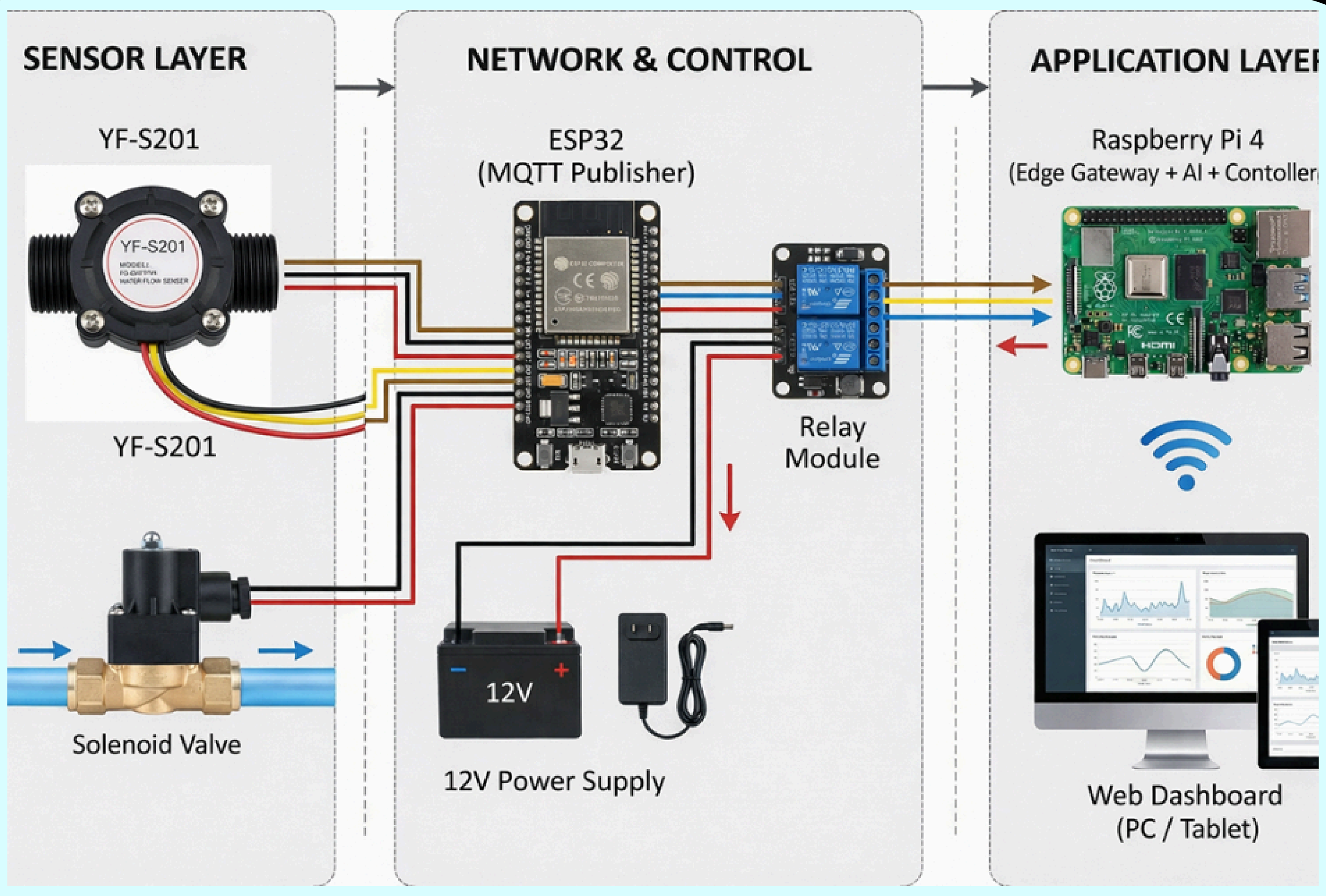
Proposed System

The system follows a three-layer IoT architecture

Perception Layer: ESP32 + YF-S201 water flow sensor collect real-time flow datA

Network &Control Layer: Raspberry Pi 4 acts as an edge gateway, MQTT broker, and AI inference unit

Application Layer: Web dashboard for monitoring, analytics, and manual control



Hardware Design

Main Components:

- ESP32 (sensing node with Wi-Fi)
- YF-S201 Water Flow Sensor
- Raspberry Pi 4 (Edge Gateway & Edge Computing Unit & Localized Server)
- 12V Solenoid Valve
- Relay Module with isolated power supply

Design Rationale:

- ESP32 ensures accurate pulse counting and wireless data transmission
- Raspberry Pi enables edge computing, local database, and TinyML inference
- Relay isolation protects low-voltage logic from high-power actuation

Software Design

Hybrid Communication Architecture

Real-Time Layer (MQTT): Usage: ESP32 → Edge Gateway

Application Layer (HTTP/REST): Usage: Edge Gateway → Backend & Frontend

Backend: Python-based MQTT subscriber and control logic,Java (Spring Boot framework)

Maven build tool

MySQL database

Frontend: Responsive Web Dashboard, Nginx web server (HTML/JavaScript),TypeScript

Dashboard Features:

Real-time water flow gauge (L/min)

Historical consumption charts ,Manual emergency shut-off control

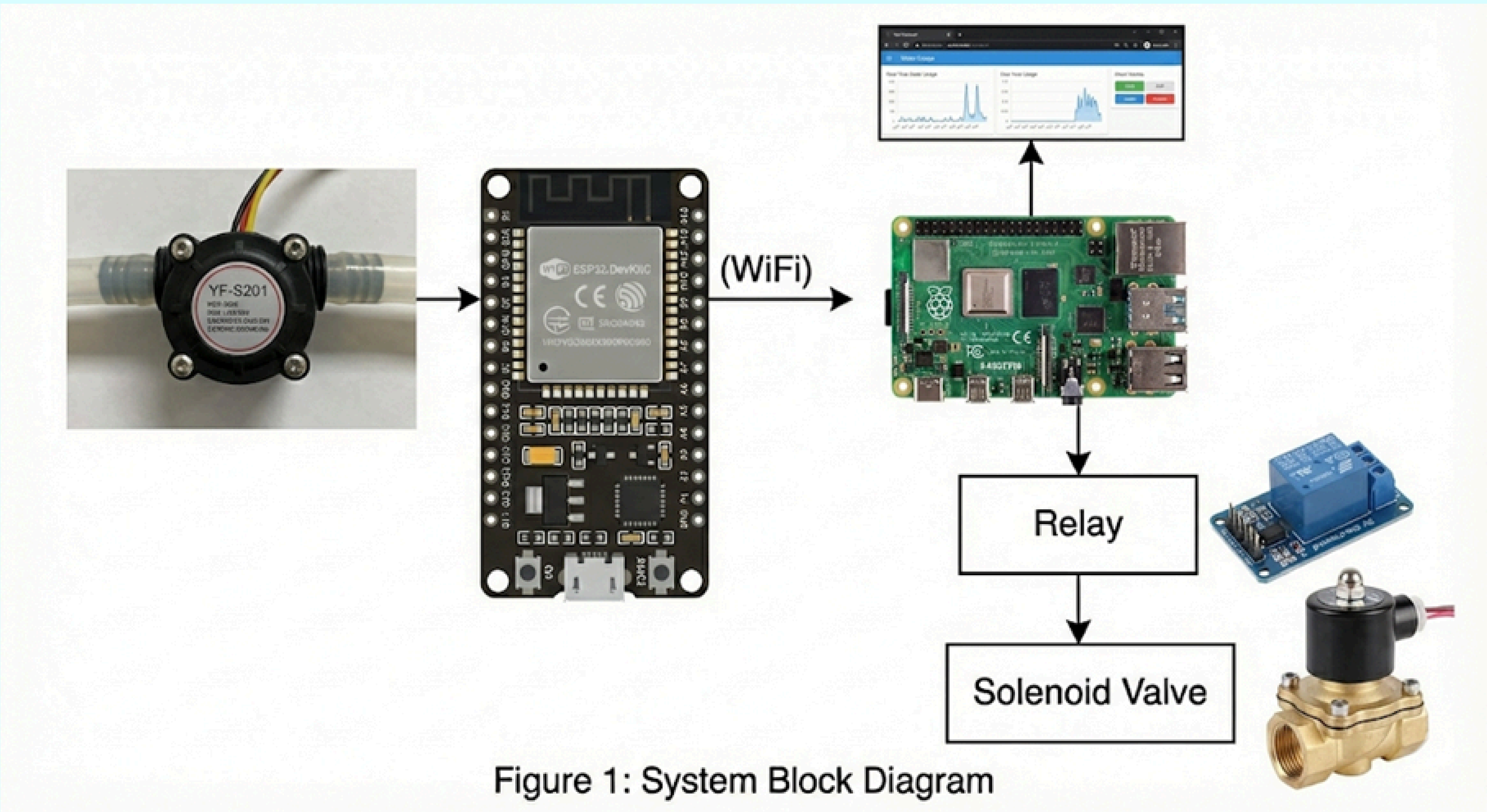
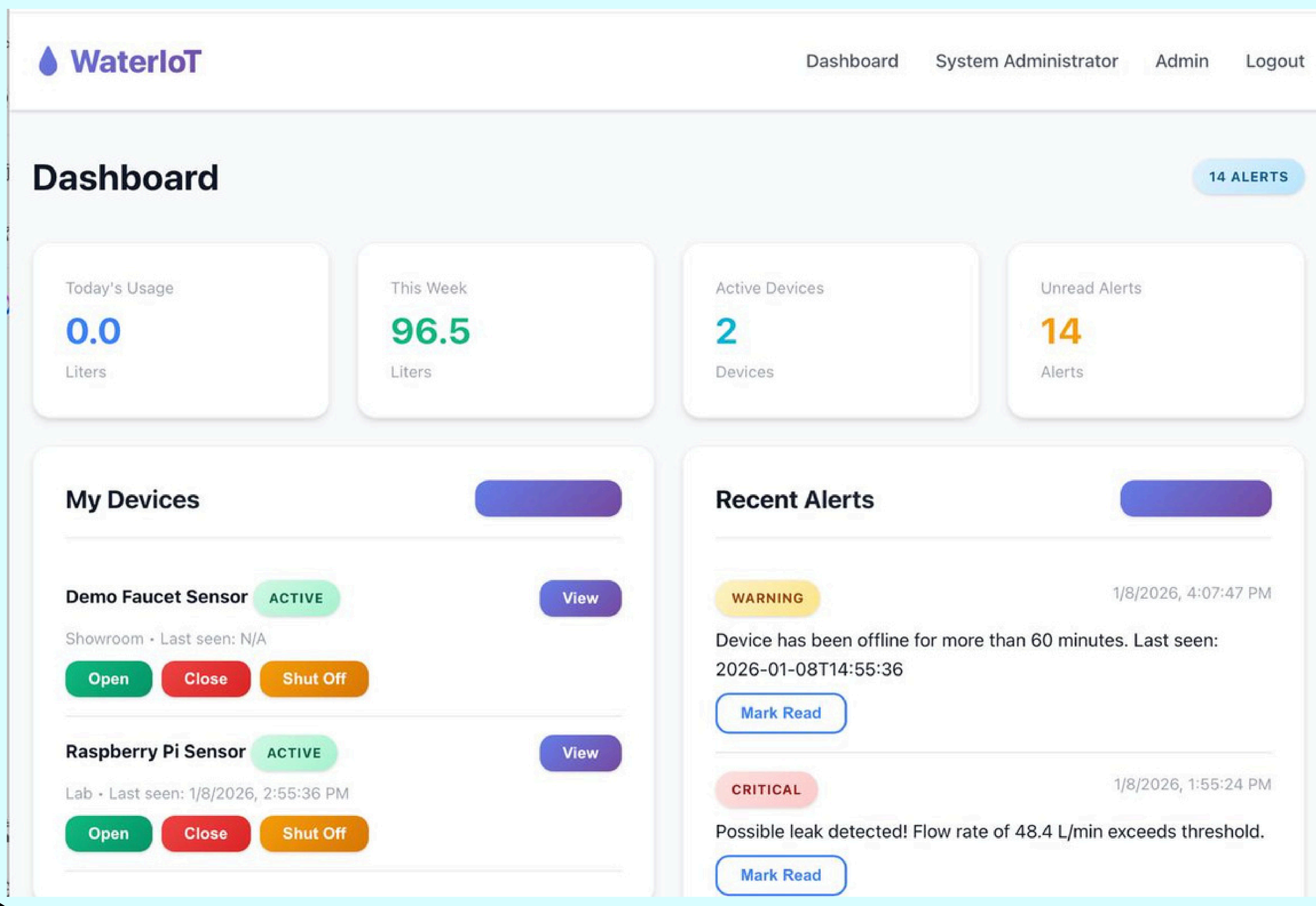


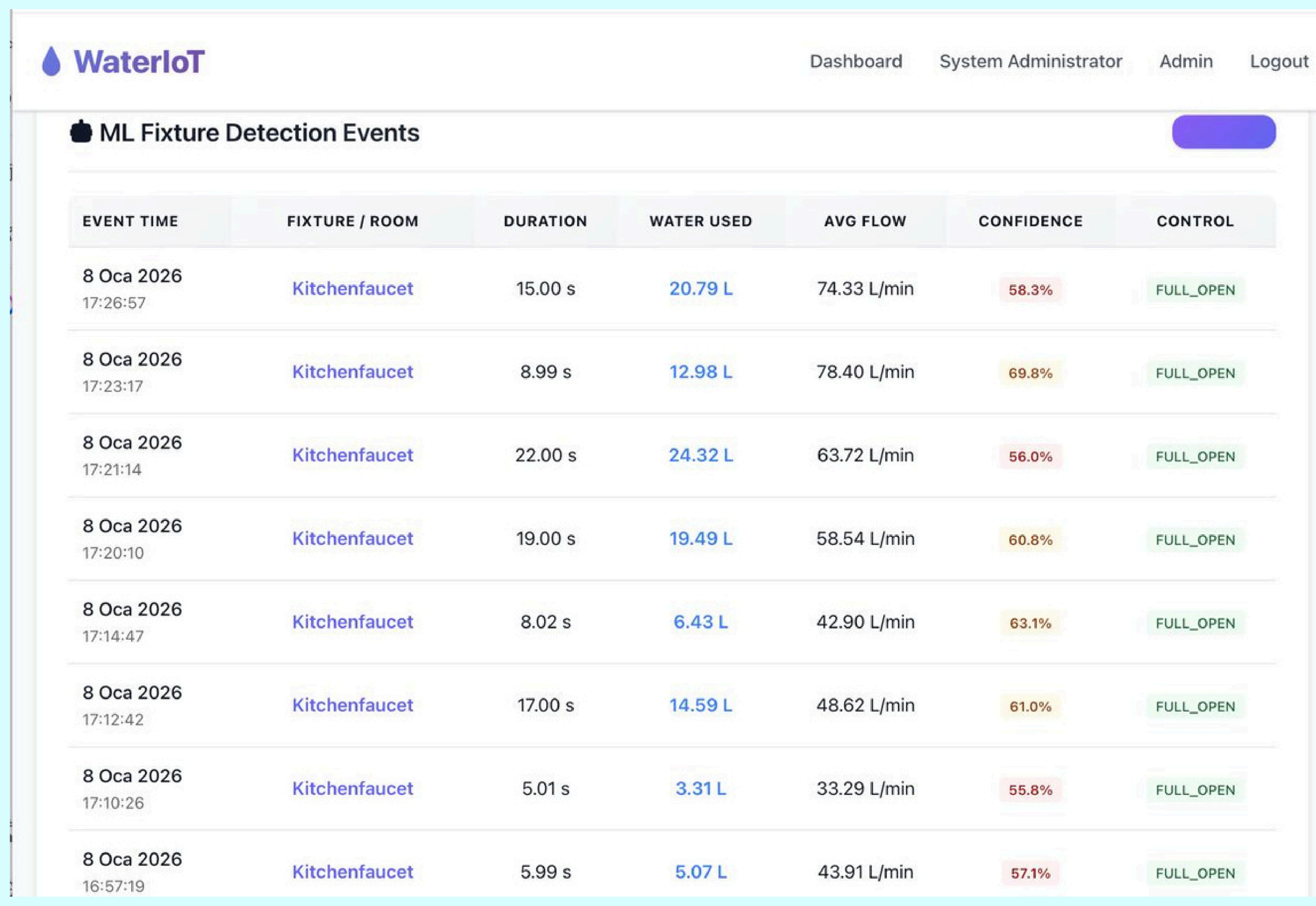
Figure 1: System Block Diagram



TinyML Design & Implementation

- Model trained on normal household consumption patterns
- Converted to RandomForestClassifier (Scikit-learn) for edge deployment

Anomaly Detection: If real-time flow deviates significantly from predicted values (e.g., high flow at night), the system automatically closes the solenoid valve and raises an alert.



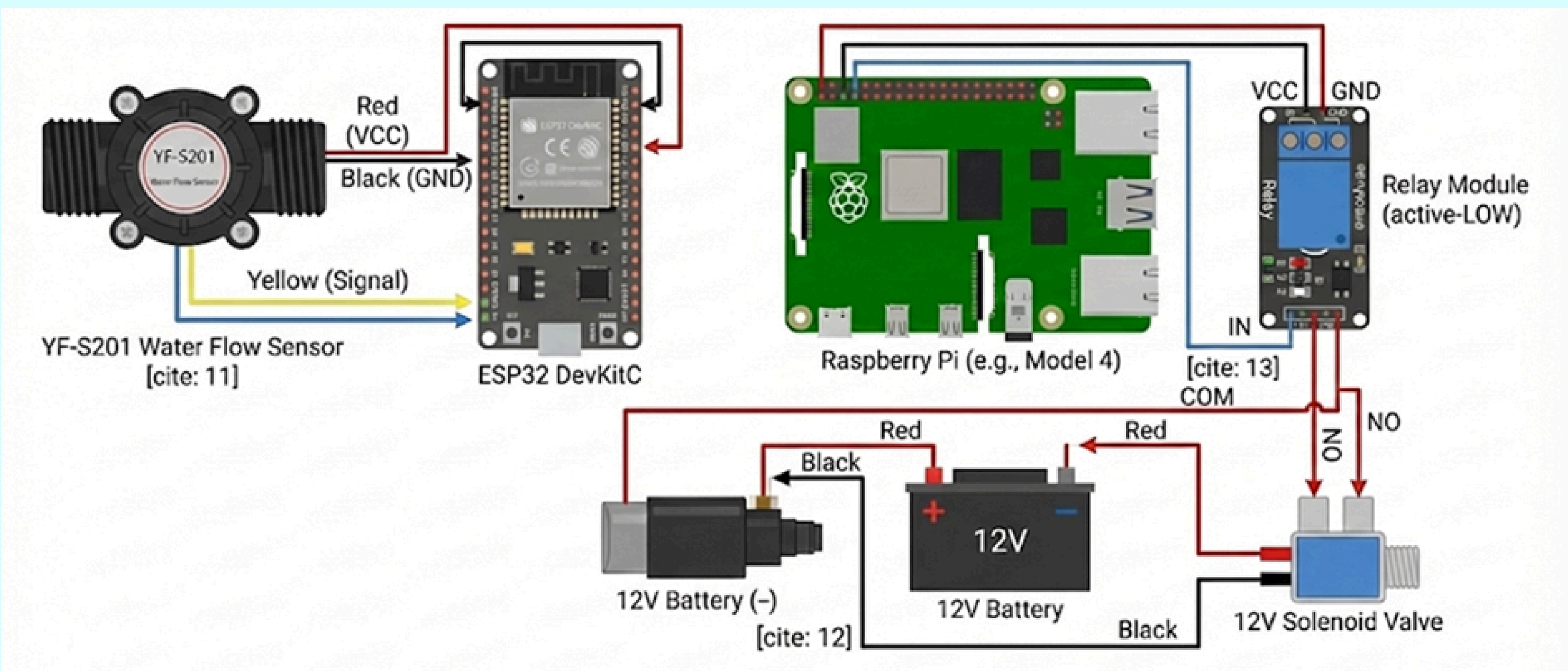


Figure 3: Integrated System Wiring Diagram: ESP32-Sensor, Pi-Relay Control, and 12V Power Circuit

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References

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