Enhanced Realtime Environmental Monitoring System:

Air Quan

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Abstract

This report presents the design and implementation of Air Quan, an enhanced real-time environmental monitoring system. The system integrates a Supabase real-time database, advanced Bluetooth communication for dynamic Wi-Fi setup, and over-the-air (OTA) firmware updates through a secured web interface deployed on Vercel. The platform ensures seamless data retention across resets and provides a real-time dashboard with one-minute telemetry updates and scheduled firmware rollout every 30 minutes. Key innovations include secret-key secured Bluetooth provisioning, dynamic network credential configuration, and administrative control for OTA updates.

Keywords

Real-time monitoring, Supabase, OTA firmware, Bluetooth security, dynamic Wi-Fi configuration, Vercel deployment

1. Introduction

Environmental monitoring is critical for applications ranging from smart homes to industrial IoT. Air Quan addresses the need for an integrated system offering real-time sensor telemetry, secure configuration management, and remote firmware maintenance using cost-effective hardware.

2. System Architecture

2.1 Hardware Components

- **Microcontroller**: ESP32 (with integrated Bluetooth & Wi-Fi)
- **Sensors**: DHT22 temperature & humidity sensor, pull-up resistor 10 kΩ

2.2 Software Components

- **Supabase**: Real-time database for telemetry and firmware metadata
- **Backend API**: Node.js/Next.js hosted on Vercel
- **Web Dashboard**: React frontend for real-time visualization and OTA control

2.3 Communication Flows

1. **Bluetooth provisioning**: device enters pairing mode, mobile app sends credentials
2. **Wi-Fi setup**: credentials formatted as <asta45>WIFI_SSID<sep@>PASSWORD<end#>
3. **Session termination**: manual end via <destroy#> command
4. **Telemetry**: sensorData table updates every 60 s
5. **OTA updates**: firmware table triggers rollout every 30 min

3. Implementation

3.1 Real-time Database Management

Supabase hosts two primary tables:

- **sensorData**
    - id (UUID, primary key)
    - timestamp (timestamptz)
    - temperature (float)
    - humidity (float)
    - device_id (text)
- **firmware**
    - id (UUID, primary key)
    - version (text)
    - release_notes (text)
    - rollout_time (timestamptz)
    - device_targets (array of text)

Authentication: JWT based API keys restrict read/write to dashboard and devices.

3.2 Advanced Bluetooth Setup

- **Pairing**: ESP32 advertises BLE service; mobile app provides secret key <asta45>
- **Credential Exchange**: SSID and password delimited by <sep@> and terminated with <end#>
- **Session End**: <destroy#> instructs ESP32 to close BLE session
- **Encryption**: Bluetooth LE Secure Connections mode ensures confidentiality

3.3 OTA Update Mechanism

- **Firmware Packaging**: compiled binary uploaded via admin web interface
- **Trigger Logic**: new entry in firmware table with rollout_time schedules update
- **Delivery**: ESP32 polls Supabase every 30 min, downloads via HTTPS, and flashes
- **Integrity**: SHA-256 checksum verified before applying

3.4 Deployment

- **Vercel**: Automatic deploy on Git push; environment variables manage Supabase keys

- **CI/CD**: GitHub Actions pipeline runs tests, lints, and triggers Vercel deployment

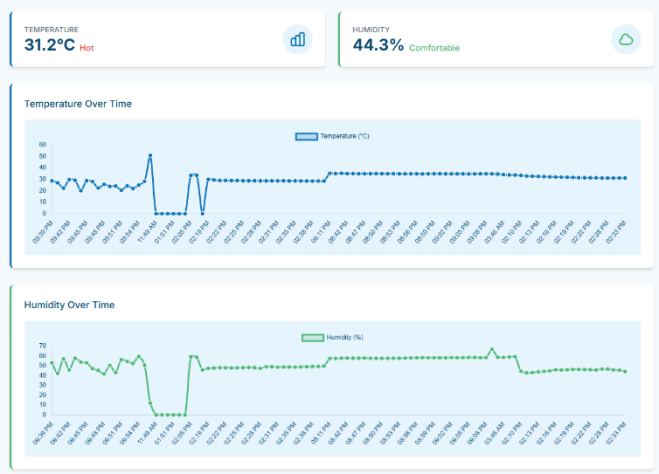

Figure 2: Web dashboard screenshot showing real-time telemetry and OTA controls

4. Results and Performance

- At present, formal latency and success-rate metrics are pending collection; preliminary tests confirm stable connectivity and reliable OTA across several cycles.

5. Discussion

- **Security**: BLE Secure Connections and checksum verification mitigate MITM and tampering
- **Scalability**: Supabase's horizontal scaling supports thousands of devices with minimal configuration

6. Conclusion

Air Quan demonstrates a robust, low-cost IoT monitoring platform combining secure provisioning, real-time telemetry, and remote firmware management. Its modular design lends itself to rapid extension for additional sensors or analytics.

7. Future Work

- Integration of gas or particulate sensors
- Machine learning models for anomaly detection on telemetry streams

References

[1] Supabase Documentation. Available: https://supabase.com
[2] Vercel Deployment Guides. Available: https://vercel.com/docs