

IOTAfy: An ESP32-Based OTA Firmware Management Platform for Scalable IoT Deployments

Ioannis Chrysovalantis Panagou^{id}, Stylianos Katsoulis^{id}, Evangelos Nannos^{id}, Fotios Zantalis^{id},
Grigorios Koulouras^{*,id}

TelSiP Research Laboratory, Department of Electrical and Electronic Engineering, School of Engineering, University of West Attica,
Ancient Olive Grove Campus, 250 Thivon Str., GR-12241 Athens, Greece

* Corresponding author

INTRODUCTION & AIM

Managing firmware updates in large-scale IoT deployments presents significant challenges regarding security, reliability, and operational cost. Physical access to devices is often impractical or expensive.

Project Aim:

- ❖ To design and implement "IOTAfy", a comprehensive, open-source Over-The-Air (OTA) firmware management platform.
- ❖ To specifically target ESP32-based IoT devices [1].
- ❖ To provide a scalable solution that eliminates the need for physical intervention and ensures secure, asynchronous updates [2], [3].

METHODOLOGY

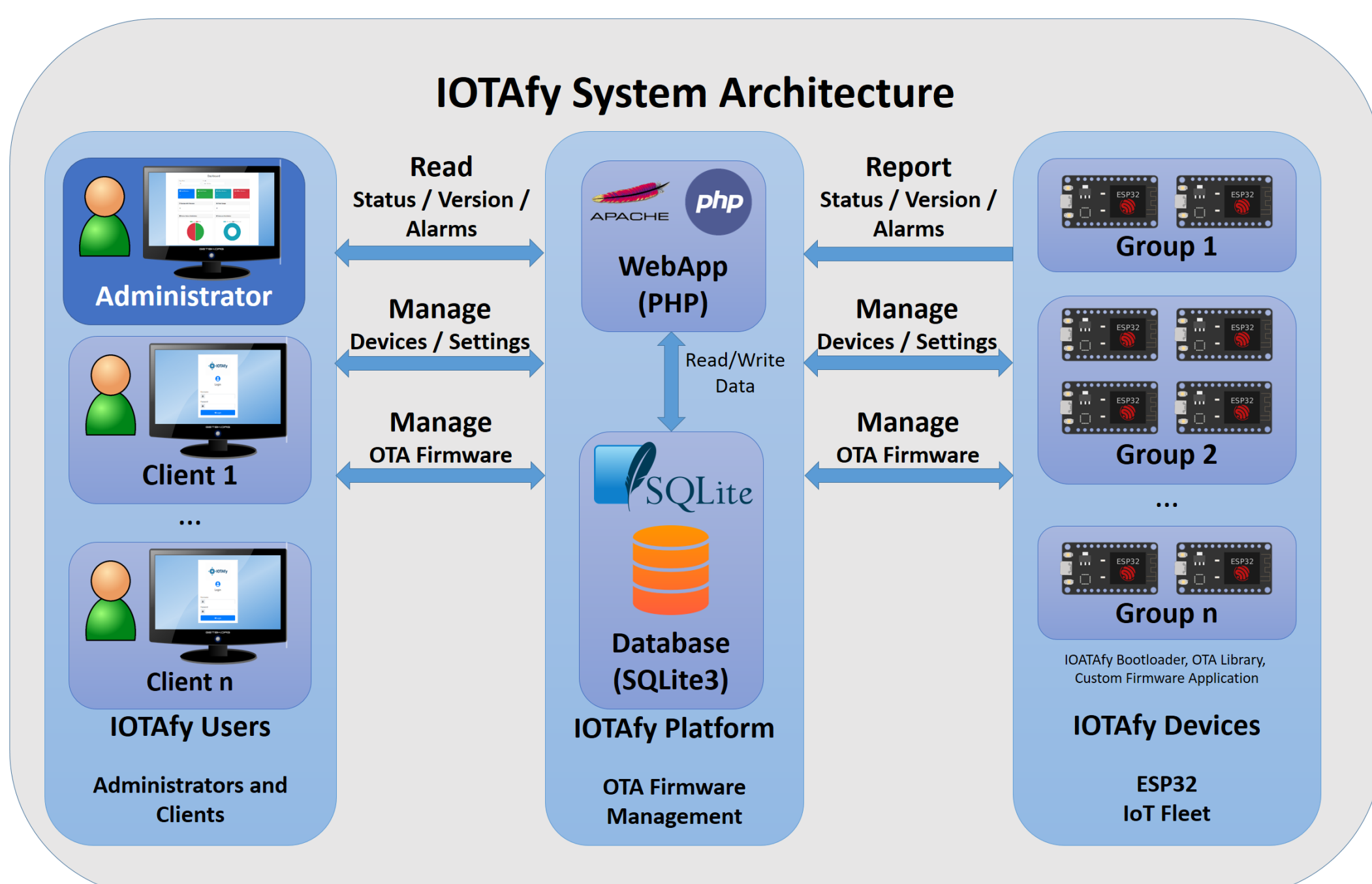
The system utilizes a robust Client-Server architecture designed for efficiency and scalability.

A. Device-Side (ESP32)

- ❖ **Components:** Custom bootloader, firmware boilerplate code, and a dedicated OTA library.
- ❖ **Mechanism:** Implements asynchronous updates to prevent device blocking during download.
- ❖ **Safety:** Built-in rollback capabilities to recover from failed updates automatically.

B. Server-Side (Management Interface)

- ❖ **Tech Stack:** PHP, SQLite3, and Bootstrap.
- ❖ **Key Features:**
 - **Centralized Dashboard:** Real-time monitoring of device status and update progress.
 - **Version Control:** Robust management of multiple firmware versions.
 - **Fleet Management:** Support for scheduled updates and group upgrades.
 - **Alerting:** Real-time notifications for update status.

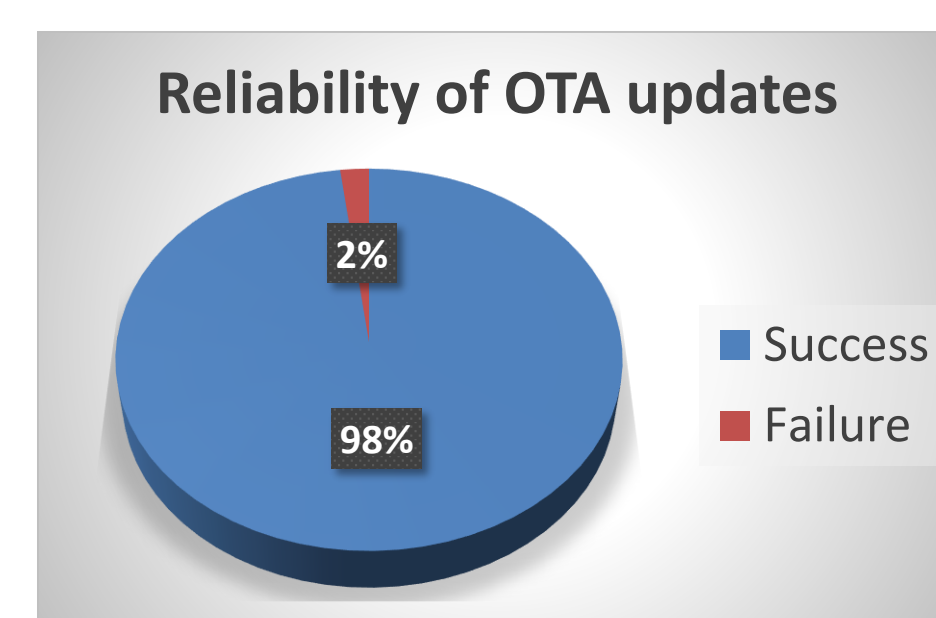
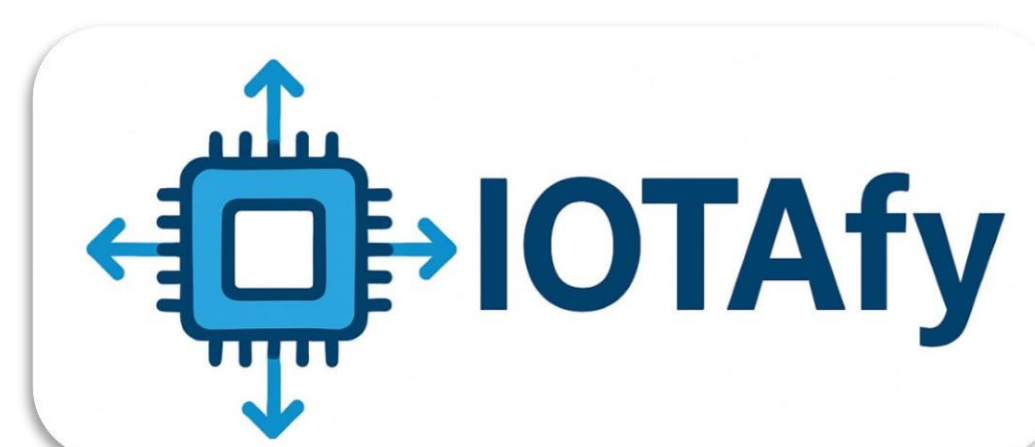


RESULTS & DISCUSSION

The platform was validated in a controlled testbed to evaluate reliability and performance.

Key Findings:

- ❖ **Test Environment:** Deployed network of 50 ESP32 devices.
- ❖ **Reliability:** Achieved a 98% success rate for OTA updates.
- ❖ **Scalability:** The efficient database design and asynchronous mechanism allow the system to scale to hundreds or thousands of devices without performance degradation.
- ❖ **Operational Impact:** Demonstrated significant cost savings and reduced maintenance time compared to manual update processes.



CONCLUSION / FUTURE WORK

IOTAfy offers a practical, scalable, and open-source solution for modern IoT infrastructure.

- ❖ Successfully addresses the security and reliability challenges of remote firmware management.
- ❖ Drastically reduces operational expenditures (OPEX) by removing physical access requirements.
- ❖ Provides a stable foundation for managing large-scale IoT fleets.

Building on the current architecture, future work aims to optimize database performance for larger device fleets and broaden hardware support.

- ❖ **Database Migration:** Transitioning from SQLite3 to PostgreSQL for enterprise-level scaling (10k+ devices).
- ❖ **Hardware Support:** Extending compatibility to other architectures (e.g., RP2040, SAMD21).
- ❖ **Security:** Implementation of end-to-end encryption for firmware payloads.

REFERENCES

- Espressif Systems, "ESP32 Technical Reference Manual," v5.6 2025.11.2, Shanghai, China, 2024. [Link](#)
- T. Bakhshi, B. Ghita, and I. Kuzminykh, "A Review of IoT Firmware Vulnerabilities and Auditing Techniques," *Sensors*, vol. 24, no. 2, p. 708, Jan. 2024. DOI: [10.3390/s24020708](#)
- V. Nikolov and D. Gotseva, "A Secure Firmware Update over the Air of ESP32 using MQTT Protocol from Cloud," in 2023 XXXII International Scientific Conference Electronics (ET), Sozopol, Bulgaria, 2023, pp. 1-4. DOI: [10.1109/ET59121.2023.10278597](#)