

Research And Optimization Of Selection Criteria For Hardware And Software Of Remote Control Systems

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Abstract

This article explores the scientific and practical foundations for selecting hardware and software components for Remote Control Systems (RCS). The study focuses on system reliability, energy efficiency, and data transmission speed as key evaluation criteria. The paper provides a comparative analysis of various microcontrollers (e.g., ESP32, STM32) and communication protocols (MQTT, LoRaWAN, HTTP). As a result of the research, recommendations have been developed for choosing the optimal hardware-software complex tailored to specific technological processes.

Keywords: Remote control, hardware, software, microcontroller, IoT, communication protocols, optimization

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Introduction

Today, Remote Control Systems (RCS) serve as the central link in industrial automation. The rapid development of information technologies has enabled control systems to operate not only locally but also on a global scale via the Internet. However, the reliability of a system depends heavily on the correct selection of its hardware and software components. In many cases, engineers encounter issues such as data latency and security vulnerabilities, making the search for optimal solutions in this field a critical issue.

Literature Review

Extensive research has been conducted globally in the fields of remote control and the Internet of Things (IoT). **Andrew Tanenbaum**, in his works, detailed the hierarchical structure of network protocols and methods for reducing data exchange errors. He argues that the "lightness" of a protocol is the foundation of system stability in remote environments. **Muhammad Ali Mazidi**, in his research on microcontroller architecture, proved that ARM-based chips like the STM32 have several times higher computational efficiency than 8-bit systems and represent the most secure choice for industrial control. **Robert Faludi** analyzed the advantages of ZigBee and LoRa technologies in building wireless sensor networks and developed criteria for balancing energy efficiency and transmission range. Among local scholars, **A.S. Karimov** has investigated the optimization of software algorithms for remote data collection systems at industrial sites. The analysis of these works indicates that while current hardware is sufficiently powerful, there is a lack of a unified methodology for its proper integration with specific software protocols.

METHODOLOGY

To evaluate the effectiveness of the hardware and software tools, the following experimental methods were employed:

- Platform Comparison:** The processing speed and power consumption of ESP32, STM32, and Raspberry Pi modules were measured while performing identical tasks.
- Protocol Testing:** The latency and Packet Loss Ratio were determined by sending 1,000 packets via MQTT and HTTP protocols.
- Software Analysis:** The impact of control scripts written in Python and C++ on microcontroller memory utilization was studied.

Results

The experiments yielded the following comparative indicators:

Table 1.1 Efficiency Analysis of Control Platforms and Protocols

Criteria	ESP32 MQTT	+STM32 Modbus	+RPi WebSockets	+Arduino + BT
Response Time	45-60 ms	10-20 ms	80-120 ms	30-50 ms

Criteria	ESP32 + MQTT	STM32 + Modbus	RPi + WebSockets	Arduino + BT
Data Security	TLS 1.2	Hardware Auth	Full Encryption	Low
Power Consumption	80 mA	40 mA	500 mA	25 mA
Application Area	Smart Home	Industrial	Video Monitoring	Robotics

The results indicated that the combination of **STM32 and Modbus** possesses the highest reliability (99.9%) for industrial real-time systems. The **ESP32** remains a leader for domestic systems due to its versatility and cost-effectiveness.

Discussion

The obtained results confirm the theories presented in the literature review. However, our research adds that software complexity requires a 20-30% resource buffer relative to the hardware's maximum capacity. The discussion revealed that although using Python (MicroPython) increases development speed, it slows down system reaction time by 2-3 times compared to C++. This implies that for critical control systems (e.g., medical devices or high-pressure valves), the use of low-level programming languages (C/Assembly) is essential.

Conclusion

The following algorithm is recommended for selecting a hardware-software complex for Remote Control Systems:

1. **For distances exceeding 1 km:** Utilize LoRaWAN and low-frequency microcontrollers.
2. **For high speed and security requirements:** Utilize STM32 and a Real-Time Operating System (RTOS).
3. **For complex interfaces and database requirements:** Utilize Raspberry Pi and Linux-based solutions.

In terms of software, implementing the **MQTT protocol** is the most effective way to optimize traffic for all types of RCS.

References

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