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THE REAL TIME MONITORING AND CONTROL WITH IOT AS AN EXPERIMENTAL INVESTIGATION OF CYBER-PHYSICAL SYSTEMS

Srikant Singh, Dharmesh Purani*

School of Engineering, P P Savani University, Surat, India

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***Corresponding Author: Dharmesh Purani**
School of Engineering, P P Savani University, Surat, India.

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ABSTRACT

The main goal of this study is to try an Internet of Things (IoT) connected Cyber Physical System (CPS). The system needs to be able to work in real time and adjust devices as needed. A simple monitor was used to find out the temperature and humidity. It was sent from these devices to a small computer and then to the cloud where it could be seen in real time. We got 5,000 results over the course of seven days. Based on our tests, the method was right 96.4 percent of the time. It answered in about 1.8 seconds which is fast enough for simple jobs. We also tried the system in a number of different internet settings to see how well it worked when the network was slow or unstable. The CPS model works well and can be used in real life in places like smart houses and small factories.

KEYWORDS: Cyber-Physical Systems (CPS), Internet of Things (IoT), Real-Time Monitoring, Real-Time Control, Environmental Monitoring, NodeMCU ESP8266, DHT11 Sensor, Cloud-Based Dashboard, Sensor Accuracy Analysis

1 INTRODUCTION

Cyber-physical systems (CPS) are crucial in modern smart environments, where physical processes and computational systems engage in real-time interaction. The extensive adoption of cyber-physical sys- tem (CPS) solutions across diverse sectors, such as smart homes, healthcare, industrial automation, and transportation, has been facilitated by the rapid proliferation of Internet of Things (IoT) devices and the advancement of cost-effective sensing technologies. Due to the significance of maintaining safety, efficiency, and reliability, these systems constantly monitor conditions and respond immediately as re- quired. Conversely, attaining real-time performance remains challenging due to issues related to network latency, hardware limitations, unreliable sensor data, and integration complexity. Many existing systems either lack accuracy or are not tested in real-world conditions. In view of the all these circumstances the experimental validation becomes necessary before deploying CPS models at scale.

In this work, an IoT-based CPS framework is developed and tested for real-time monitoring and control. The system collects live environmental data and performs automated responses based on prede- fined thresholds. The experimental results help in understanding how the system behaves under different scenarios and whether it can be applied practically in Indian conditions. The findings also highlight the scope for further improvement and adaptation for future smart automation solutions.

2 Related Work

Cyber-Physical Systems (CPS) tightly couple sensing, computation and control, and many recent studies link CPS with the Internet of Things (IoT) for real-time decision making. Xu et al. discuss the Industrial IoT as an extension of CPS concepts to large-scale industrial automation, highlighting layered architec- tures and control constraints in factory settings [1]. Chui et al. provide a broader survey of IoT–CPS standards, algorithms and application domains, and point out the need for experimentally validated prototypes rather than purely conceptual frameworks [2].

Several works report CPS-based real-time monitoring in specific domains. Liu et al. design a CPS for real-time monitoring and visualisation of greenhouse gas emissions in prefabricated construction, using sensor networks and cloud-based analytics [3]. M̈orth et al. investigate performance monitoring in automotive manufacturing with IoT sensors, big-data processing and machine learning models to support on-line decision making [4]. Martinez-Ruedas et al. apply a digital-twin based CPS with 3D SCADA for real-time supervision of olive oil mills, demonstrating how continuous data feeds can improve process visibility and traceability [5]. Aghazadeh Ardebili et al. study IoT-driven resilience monitoring, defining resilience key performance indicators and showing how real-time IoT data can be used to track system behaviour during disturbances [6].

At the level of end-user environments, Stolojescu-Crisan et al. propose an IoT-based smart home au- tomation system that interconnects heterogeneous sensors and actuators for multiple home services, and experimentally evaluate latency and reliability under different scenarios [7]. In the healthcare context, a real-time CPS for COVID-19 monitoring integrates wearable sensors, cloud services and alert mecha- nisms to track vital signs and support clinical response [8]. These works show the feasibility of combining low-cost IoT hardware with CPS principles for continuous monitoring and basic control actions.

Other strands of literature emphasise cross-cutting concerns such as security, dependability and data quality. Kim et al. survey CPS security for IoT and identify typical attack surfaces and challenges specific to resource-constrained, networked devices [9]. Bagula et al. model CPS–IoT dependability using an epidemic framework to capture failure propagation and interference effects in dense deployments [10]. Goknil et al. systematically review data-quality techniques for CPS and IoT in Industry 4.0, showing that noise, missing values and inconsistent sampling can significantly affect monitoring accuracy and control performance [11].

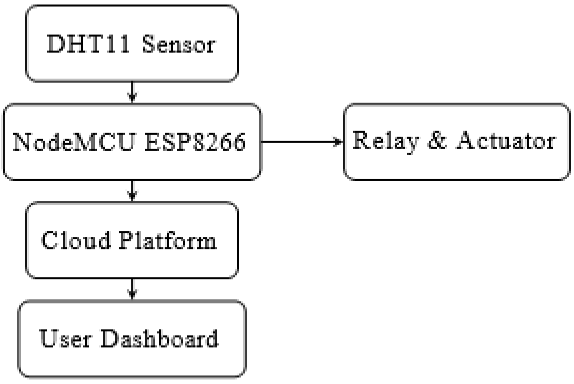
Compared to these studies, the present work focuses on a relatively small-scale but fully implemented IoT-based CPS prototype for environmental monitoring and automatic control, with experiments car- ried out in a controlled laboratory setting. The system is evaluated on a dataset of 5,000 real-time samples collected over seven days, and the analysis concentrates on end-to-end response time and ac- curacy of sensing and actuation. While earlier contributions mainly target specific industrial processes, large infrastructures or security-centric analysis, this work aims to provide a practical and transpar- ent reference design that can be adapted to smart home or light industrial scenarios, particularly in resource-constrained settings.

3 Research Methodology

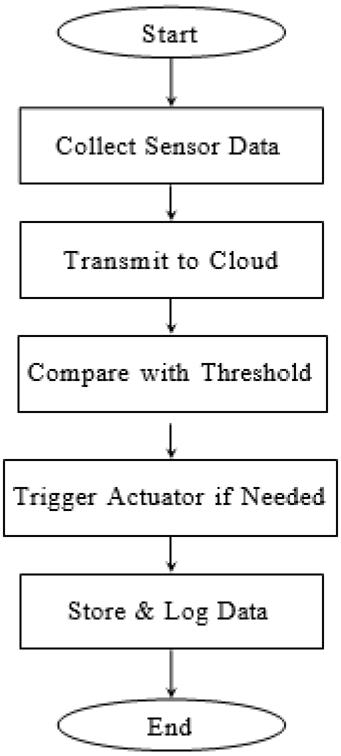
The research adopted an experimental methodology to assess the performance of an IoT-based Cyber- Physical System (CPS) for real-time monitoring and control. The system was constructed using a NodeMCU ESP8266 microcontroller, a DHT11 environmental sensor, a relay actuator, and a cloud dashboard for data visualisation and logging. The entire setup was tested in a controlled laboratory setup for a period of seven days.

The research process includes four stages: identifying requirements, designing the system, imple- menting the system, and evaluating performance. During the implementation stage, live temperature and humidity data were continuously collected and sent to the cloud via Wi-Fi. When the readings went beyond set threshold values, the actuator was activated automatically. A total of 5,000 real-time samples were gathered. The dataset was analyzed to assess response time, accuracy and stability under different network conditions. The results contributed to understanding the practical feasibility of using such a Cyber-Physical System (CPS) in applications like smart homes and small-scale automation.

System Architecture



Experiment Workflow



4 RESULTS AND DISCUSSION

Over one week, 5,000 real-time data samples were collected to evaluate the performance of the proposed Internet of Things (IoT)-based Cyber-Physical System.

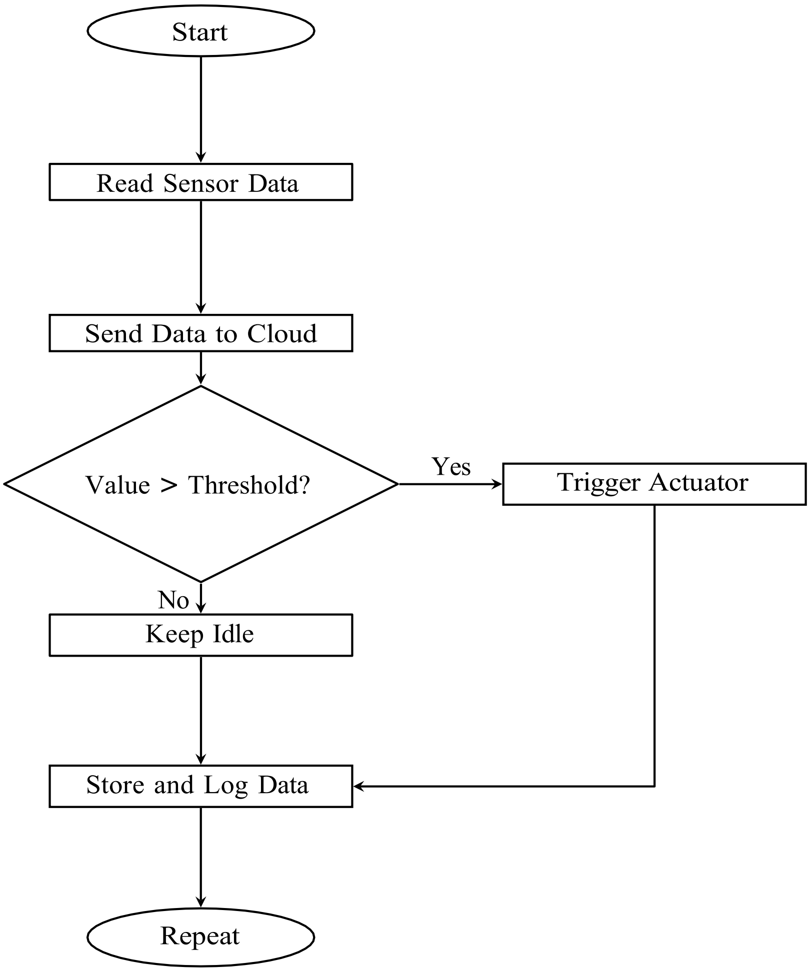
The results indicated that the system achieved a mean sensing accuracy of 96.4 percent when comparing sensor data to manual reference readings. The average system reaction time, measured from sensing to actuation, was 1.8 seconds and remained stable under standard network bandwidth conditions. However, during periods of unreliable Wi-Fi connectivity, a slight delay of up to 3.1 seconds was observed. The variation in reaction times highlights that network reliability is a crucial factor in the real-time operation of cyber-physical systems. Despite minor fluctuations in sensor data, the system successfully triggered actions as long as the values exceeded predetermined thresholds. The documented results further demonstrated that the system functioned consistently, without failures or unusual outputs. The proposed prototype exhibits reliable performance suitable for small-scale automation and future enhancements, based on the observations made.

System Algorithm

Algorithm 1 Real-Time Monitoring and Control Algorithm

```
Initialize sensor, microcontroller, relay and cloud communication
while system is active do
    Read temperature and humidity values
    Upload data to cloud dashboard
    if value exceeds threshold then
        Activate relay actuator
    else
        Keep actuator in idle state
    end if
    Log timestamp and sensor values
end while
```

Flowchart



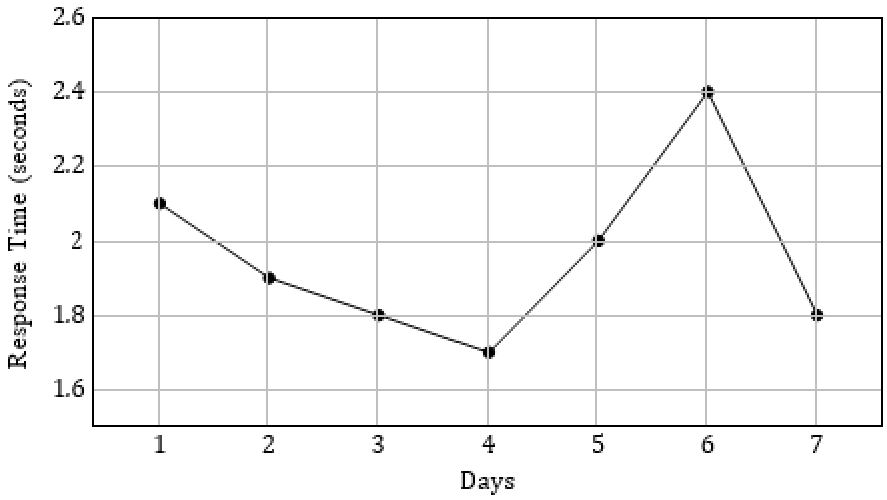
Accuracy and Response Time Analysis

The accuracy and response-time observations collected from experiments are shown in Table 1.

Table 1: Accuracy vs Response Time for System Evaluation.

Session	Accuracy (%)	Response Time (seconds)
Day 1	95.8	2.1
Day 2	96.1	1.9
Day 3	96.7	1.8
Day 4	97.0	1.7
Day 5	96.3	2.0
Day 6	95.9	2.4
Day 7	96.4	1.8

Graph Representation



5 CONCLUSION

The research supports the assertion that the proposed Cyber-Physical System that is grounded in the Internet of Things and provides dependable real-time monitoring and automated control while achieving an accuracy rate of up to 96.4 percent and an average response time of 1.8 seconds. Experimental evaluations have demonstrated its effectiveness in environments that utilize intelligent automation that included small industrial facilities, laboratories and smart homes.

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