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Towards smart agriculture : Optimizing IoT device energy efficiency with cloud-based load balancing

Sneha *
Prabh Deep Singh †
Vikas Tripathi §
Department of Computer Science and Engineering
Graphic Era (Deemed to be University)
Dehradun 248001
Uttrakhand
India

Abstract

Smart agriculture revolutionizes traditional farming by leveraging advanced technologies for enhanced efficiency and sustainability. The study focuses on optimizing IoT device energy efficiency in smart agriculture through Cloud-Based Load Balancing. This tri-layer cloud-based architecture integrates IoT, Dew Computing, and Cloud Computing, streamlining time-sensitive data processing. The Dew Computing layer optimizes data processing, reducing latency and enhancing efficiency. The Round Robin Scheduler in the IoT layer ensures fair resource distribution, enhancing energy efficiency. Performance evaluations show reduced response times, optimized resource allocation, and enhanced farming productivity, emphasizing the importance of Cloud-Based Load Balancing in advancing sustainable agriculture practices.

Subject Classification: *94-XX.*

Keywords: *Smart agriculture, IoT, Cloud computing, Dew computing, Load balancing.*

1. Introduction

Smart agriculture offers a paradigm shift in traditional farming operations, incorporating cutting-edge technologies to improve efficiency, sustainability, and productivity [1]. Smart agriculture relies on a wide

* *E-mail:* **snehaji7456@gmail.com (Corresponding Author)**
† *E-mail:* **ssingh.prabhdeep@gmail.com**
§ *E-mail:* **vikastripathi.cse@geu.ac.in**

range of networked technology. By allowing for data acquisition in real-time from the field, incorporating IoT devices—including sensors, drones, and actuators—has utterly transformed the agricultural industry. Soil moisture, crop health, weather, and machinery performance data help farmers make informed decisions, allowing them to maximize resource use, increase crop yields, and proactively adjust to changing environmental conditions.

By offering a centralized platform for processing, storing, and analyzing massive amounts of data produced by agricultural IoT sensors, cloud computing supplements IoT. Data analytics become more efficient with the help of the Cloud's scalability and computing power, which enable complex algorithms to gain valuable insights. This frictionless integration encourages data-driven decision-making on a scale never before possible, and real-time monitoring is made possible [2].

Better resource utilization, less environmental effects, higher crop quality, and higher agricultural output are all outcomes of this integration. Through the Internet of Things (IoT) and cloud computing, farmers can build an adaptive agricultural ecosystem that goes beyond the old trial-and-error methods. Thus, to tackle the issues posed by a rapidly expanding human population and an altering global climate, smart agriculture will play an essential role in building food production systems that are both sustainable and resilient.

2. Proposed Architecture

The tri-layer cloud-based architecture for agricultural data processing comprises three interconnected layers: IoT, Dew Computing, and Cloud. Each layer serves a distinct purpose, contributing to the seamless flow and efficient processing of time-sensitive agricultural data. Figure 1 shows the Tri-Layer Cloud-Based Smart Agriculture Architecture.

IoT Layer: The IoT layer is the foundation of the architecture, consisting of a network of sensors and drones strategically deployed across agricultural fields. These devices act as data collection points, capturing real-time information on various environmental factors such as soil conditions, weather patterns, and crop health [4]. Sensors and drones within the IoT layer communicate to form a comprehensive network, gathering data crucial for informed agricultural decision-making.

Dew Layer: Dew Computing represents a paradigm that extends cloud computing to the network's edge, focusing on local processing and data optimization. Unlike traditional cloud computing, which centralizes

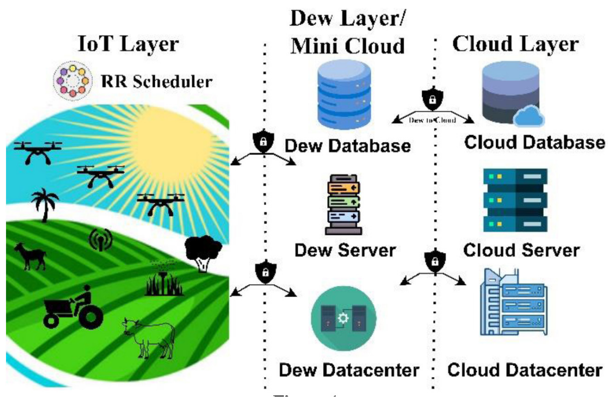

Figure 1

Tri-Layer Cloud-Based Smart Agriculture Architecture [3]

data processing in remote servers, Dew Computing emphasizes distributing computational tasks closer to the data source [5]. This approach enhances efficiency, reduces latency, and addresses the challenges of transmitting extensive raw data over the network. Dew Computing is an intermediary layer between IoT and the centralized Cloud, optimizing data processing for specific applications or domains.

The Dew Computing layer connects the IoT and Cloud layers within the proposed tri-layer cloud architecture. Positioned strategically, this layer is responsible for preprocessing and optimizing the time-sensitive agricultural data collected by the IoT devices. By taking on these tasks locally, the Dew Computing layer acts as a buffer, reducing the immediate processing burden on the IoT devices and minimizing time delays associated with transmitting raw data directly to the Cloud.

This intermediary layer enhances the overall efficiency of the agricultural data processing pipeline by introducing intelligence and optimization closer to the data source [6]. The Dew Computing layer reduces redundancy in the data and schedules tasks judiciously to ensure that critical information reaches the Cloud layer promptly.

Efficient Algorithm - Round Robin: When integrated into the IoT layer in agricultural settings, the Round Robin(RR) Scheduler significantly enhances the energy efficiency of IoT devices. By ensuring a fair distribution of processing power and resources among devices, preventing resource monopolization, and optimizing task execution through a precise time-slicing strategy, the scheduler promotes balanced resource utilization [7]. The adaptive preemption strategy and the efficiency of the circular queue

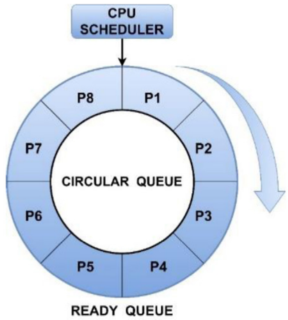

Figure 2

Working of RR Scheduling [8]

mechanism contribute to minimizing idle time and dynamically allocating resources, leading to energy-efficient operations. In time-sharing systems, the RR scheduling strategy is a commonly used methodology. A precise quantum or time slice has been designated, frequently prolonged between 10 and 100 milliseconds [8]. The CPU scheduler successively sweeps the ready queue, apportioning the CPU to each job for a maximum of one-time quantum (TQ). The ready column is presumed to be a circular queue. The system will investigate whether process P1 has finished execution regardless of whether it passes through the end of the line. Figure 2 shows the working of RR Scheduling.

If P1 has accomplished its execution, it is unnecessary to request the CPU again. However, if P1 does not finish its execution within the initial TQ, the CPU will be returned to P1, granting it another TQ to execute before moving on to the subsequent process.

Cloud Layer: The Cloud layer represents the centralized processing hub where extensive data analysis, storage, and decision-making occur. It leverages the computational power of cloud servers to handle complex algorithms and conduct in-depth analyses based on the preprocessed data received from the Dew layer [9]. Agricultural stakeholders, researchers, and farmers can access the insights generated by the Cloud layer through user-friendly interfaces, enabling them to make timely and informed decisions that positively impact agricultural practices.

3. Performance Evaluation of Proposed Architecture

The study of the architecture's performance in agricultural contexts demonstrates that it effectively reduces response times, optimizes resource

Table 1
Burst, Waiting, and Turn-Around Time of Cloudlets

S. No.	Average BT, WT, and TAT on Total			
	No. Of Cloudlets	BT	WT	TAT
1.	4	8.34	2.72	4.81
2.	8	18.66	8.36	10.69
3.	12	24.49	10.88	12.92
4.	16	29.69	13.78	15.64

allocation, and improves output. The examination underlines the potential of the architecture to bring about a paradigm shift in task scheduling within agricultural practices, resulting in enhanced productivity and efficacy of farming operations. Table 1 shows cloudlets' burst, waiting, and turnaround times.

Burst Time of Cloudlets: Burst time(BT) evaluates the true duration of time a process must spend to finish running, including the time required for computation and resource access [10]. Figure 3 shows the average BT of Cloudlets.

Waiting Time of Cloudlets: The waiting time(WT) for a process/ cloudlet refers to the cumulative duration during which a process remains in the ready queue, awaiting its turn to be allocated CPU time for execution. The metric quantifies the period a process spends in the line before commencing execution [11]. Figure 4 shows the average WT of Cloudlets.

Turn-Around Time: The turnaround time(TAT) of a process refers to the overall duration required for the process to finish its execution, encompassing both the waiting time and the execution time. The metric

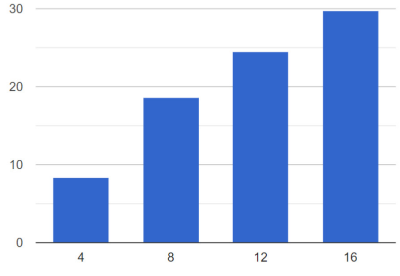

Figure 3
Average Burst Time of Cloudlets

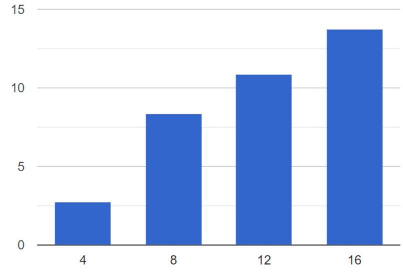

Figure 4
Average Waiting Time of Cloudlets

quantifies the period between initiating and completing a procedure [12]. Figure 5 shows the average TAT of Cloudlets.

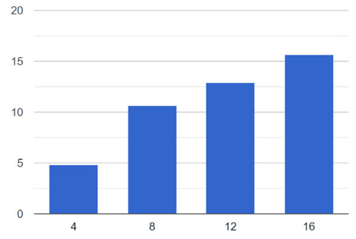

Figure 5

Average Turn-Around Time of Cloudlets

4. Result and Conclusion

Smart agriculture's transformational impact is obvious in integrating modern technology, such as IoT devices, which have revolutionized traditional farming processes. The suggested tri-layer cloud-based architecture, which seamlessly integrates IoT, Dew Computing, and the Cloud, emerges as a critical solution for improving time-sensitive agricultural data processing. The Round Robin Scheduler, strategically placed within the IoT layer, emerges as a critical component in increasing energy efficiency by assuring equitable resource distribution. Comprehensive performance evaluations reveal that Cloud-Based Load Balancing reduces reaction times, optimizes resource allocation, and increases farming productivity, highlighting its value in developing sustainable agriculture practices. This system demonstrates its ability to transform job scheduling paradigms in agriculture, promising increased production and operational efficiency. The thorough integration of Cloud-Based Load Balancing is critical in propelling sustainable and technologically sophisticated agriculture practices into the future.

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