engineering proceedings

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Proceeding Paper

Energy-Aware Load Balancing in a Cloudlet Federation †

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† Presented at the 1st International Conference on Energy, Power and Environment, Gujrat, Pakistan, 11–12 November 2021.

Abstract: With the rapid increase in computation-intensive tasks, the current research task is to minimize energy consumption due to resource constraints and increased cost. For complex computations where multiple computer systems are required to execute a single task such as in a federated cloudlet environment, load balancing is the main challenge. Load balancing means dividing the total workload between all the present nodes to obtain the maximum benefits from the available resources and to minimize energy consumption. A cloudlet is a resourceful computer that is coupled to the Internet and is accessible for mobile devices in their vicinity. A Cloudlet Federation is the concept of a cooperative framework to share resources and load balancing among various cloudlets. Different tasks consume different amounts of energy for their execution, which results in a large amount of heat dissipation. Due to heat, the performance of the systems is decreased. The more heat is present, the more the performance degrades. To address this problem, this paper proposes a novel scheduling strategy that will assign incoming tasks to systems according to their energy consumption level. The proposed methodology is tested in a Cloudlet Federation environment and the results show improved load balancing in terms of energy consumption and heat dissipation.

Keywords: energy efficiency; task arrival; cloudlet federation; power consumption; load balancing

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Citation: Inam, M.; Nayyer, M.Z. Energy-Aware Load Balancing in a Cloudlet Federation. *Eng. Proc.* **2021**, *12*, 27. https://doi.org/10.3390/engproc2021012027

Academic Editor: Sajjad Miran

Published: 23 December 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

The core function of a computer system is to assist in meeting the end user's requirements. All computer systems have a CPU as the key component for scheduling and management of different tasks on the basis of available resources [1,2]. Different task scheduling algorithms have been offered in previous years for scheduling the tasks to obtain the maximum output [3].

Cloudlet federation provides different types of services such as computing and data storage [1]. In Cloudlet Federation, systems are virtualized for maximum utilization of the available resources to meet the increasing user demands regarding various services. Greater energy consumption in the Cloudlet Federation results in the increased computational cost and release huge amount of carbon dioxide CO_2 [2,3].

Keeping in mind the significance of power saving, various techniques and algorithms such as PALB (Power Aware Load Balancing), e-STAB (Energy-Efficient Scheduling for Cloud Computing Application with Traffic Load Balancing), DDR (Dynamic Round Robin), and MAX-MIN, etc. are presented in the literature. These techniques do not consider the energy level of the system on which the tasks are running [4,5].

All the above-mentioned techniques have their own advantages and disadvantages. Some techniques balance the load on the basis of incoming tasks regardless of their power consumption [6–8]. The proposed technique observes how much energy a task will consume for its execution and also considers the power state of the system and then on the basis of this information selects the optimal system for task execution. To the best of our knowledge, this kind of technique has not been reported in the literature which deals with the challenge of best resource optimization in a Cloudlet Federation based on energy. The rest of the paper is organized as follows. Section 2 describes the proposed energy aware load balancer and optimal system selection algorithm. Performance evaluation is presented in Section 3. Section 4. consists of the conclusion and future directions.

2. Energy Aware Load Balancer

The proposed technique provides an energy-aware load balancing which focuses on the energy of the system in which there are different choices of selecting present systems at a Cloudlet Federation. The suitable system has minimum total energy T_g according to the current situation. This technique requires a list of systems, list of power consumption for each system and list of running tasks. A simpler presentation of proposed framework is shown in Figure 1.

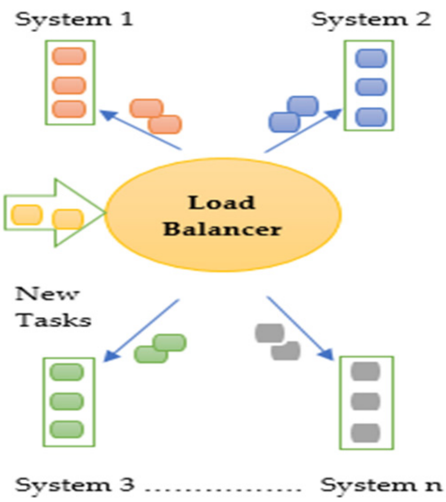

Figure 1. Proposed technique for load balancing.

New tasks are present in the queue and wait for the balancer that assigns them to the available systems by balancing the load equally to maximize the usage of the available resources while minimizing the energy consumption at each system. The proposed energy-aware load balancer schedules the task to the system with minimum energy consumed on the basis of a smaller amount of required energy for its completion.

2.1. System Energy Calculation

The total energy of a system contains the sum of energies of all the tasks executing on it from i to n and can be computed by using the below equation:

$$T_g = g_1 + g_2 + g_3, g_4, \ldots, g_n$$

where g_1, g_2 are the total energy of task 1 and task 2, respectively, etc. The total energy consumed by a task to execute on an allocated system can be computed as:

$$g = P * t$$

where 'P' is the processor power of current system and 't' is burst time of task.

2.2. Optimal System Selection

The presented Algorithm 1 focuses on searching the optimal system for execution of tasks. The algorithm takes the systems list, their power state, energy requirements for the tasks as input values, checks the status of system and then after conducts the comparison, finding the available optimal system.

Algorithm 1: Optimal System Selection (OSS)

Input: List of systems,
List of power consumption for each system,
List of running task on each system
Output: Optimal system S_o
Begin:
Let optimal system S_o be *NULL*
for each task at load balancer **do**
Check status T_c, T_e, and T_n
If T= new
for each select system with min P/C **do**
Check T_g
If $S_i <= S_i + 1$
end for
end if
$S_o = S_i$ with minimum T_g
end for
return S_o
end:

3. Performance Evaluation

In this section, performance analysis of the offered technique introduced in Section 2 was studied.

3.1. Performance Metrics

To differentiate the effectiveness of the presented technique, several performance metrics were chosen. The first one is task arrival time A_t, the second is the waiting time W_t, the third metric is the execution time T_e of the task and the fourth metric is the power consumption of the system.

3.2. Experimental Setup

This setup was installed in a Cloudlet Federation on systems with a 2.4 GHz Intel Core i3-2370 M processor, RAM 2 GB, DDR3 drive and 3 MB cache. The proposed model was installed with the help of 3 systems. Figure 2 shows a representation of the setup.

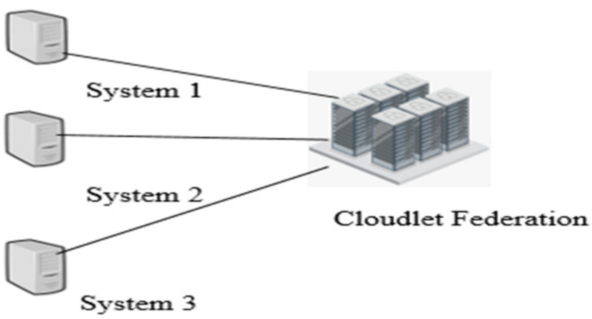

Figure 2. Experimental setup.

3.3. Results

The proposed algorithm was executed three times to attain an optimal system with an average minimum amount of energy. Results from the experimental setup are shown in Table 1.

Table 1. Table of results.

Technique Name	Total Time	Consumed Energy
PALB	0.793 s	11.8 J
STAB	1.04 s	15.6 J
DRR	0.87 s	13.0 J
EALB	0.58 s	8.7 J

The proposed algorithm was compared with different techniques such as PALB, STAB and DRR and the experimental results show that our proposed technique outperforms other techniques in terms of energy consumption.

4. Conclusions and Future Directions

Load balancing is a popular and challenging research area in current age, which involves effective distribution of the load to the available systems. In this paper, an energy-aware load balancing technique is introduced which will assist in finding the optimal system in task scheduling for the best utilization of resources to save maximum energy. The main goal of the work was to balance the load by efficiently allocating the load to the servers. In future, other performance parameters such as execution time and carbon dissipation can also be considered to develop a more efficient algorithm to enhance the best resource usage to save energy while improving performance.

Conflicts of Interest: There's no financial/personal interest or belief that could affect the objectivity of this work leading towards potential conflict.

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