RESEARCH ARTICLE OPEN ACCESS

# Implementing Workload Postponing In Cloudsim to Maximize Renewable Energy Utilization

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**ABSTRACT**
Green datacenters has become a major research area among researchers in academy and industry. One of the recent approaches getting higher attention is supplying datacenters with renewable sources of energy, leading to cleaner and more sustainable datacenters. However, this path poses new challenges. The main problem with existing renewable energy technologies is high variability, which means high fluctuation of available energy during different time periods on a day, month or year. In our paper, we address the issue of better managing datacenter workload in order to achieve higher utilization of available renewable energy. We implement an algorithm in CloudSim simulator which decides to postpone or urgently run a specific job asking for datacenter resources, based on job's deadline and available solar energy. The aim of this algorithm is to make workload energy consumption through 24 hours match as much as possible the solar energy availability in 24 hours. Two typical, clear and cloudy days, are taken in consideration for simulation. The results from our experiments show that, for the chosen workload model, jobs are better managed by postponing or urgently running them, in terms of leveraging available solar energy. This yields up to 17% higher utilization of daily solar energy.
***Keywords:*** green datacenters, energy consumption, renewable energy, solar energy, simulator

## I. INTRODUCTION

Today's green datacenters mean energy efficient, sustainable and eco-friendly system. With the advances of renewable energy technology, wind and solar energy sources are rapidly becoming clean substitutes of fuel based sources of energy. Many giants of datacenters such as Google, Amazon, Facebook, HP, etc have begun to supply their datacenters with renewable energy and they aim to achieve 100% coverage in the near future [1], [2]. However, because of their intermittency and variations through periods of time, the integration of renewable energy resources into datacenter is very challenging. Usage of energy storage is usually costly and not eco-friendly.

In this paper, we prove that workload flexibility in Cloud Computing data centers can offer a unique opportunity to tackle the challenges in integrating renewable energy resources. This would better make use of the available renewable energy and also lower the datacenter's carbon footprint. To achieve these objectives, we propose and implement an algorithm which decides to postpone or urgently run a specific job asking for datacenter resources, based on job's deadline and available solar energy. After implementing it in a well known simulator called CloudSim, we run experiments to show that, by better managing the coming workload of a datacenter, there is a great opportunity to integrate renewable energy as supplier for datacenters. Implementing the algorithm in CloudSim is the main contribution of this paper, as no other study reports to have done this before.

The paper is organized as follows. Section 2 presents related works of the field. At Section 3, we describe datacenter, workload and renewable energy characteristics used for our study. An introduction to the simulator and the proposed algorithm are also included. Section 4 presents the experiments and results to finalize with conclusions at Section 5.

## II. RELATED WORK

There have been studies, mostly in the latest decade, regarding renewable energy integration as datacenter's energy source. There are basically two main categories of studies and research in this field, in terms of:

- Real implementation or simulator: the algorithm is implemented in real environment of a physical datacenter or it's implemented and tested in a simulator, where more scenarios are possible.
- 1 single datacenter or geographically distributed datacenters. If the input is one datacenter, the goal is to manage the workload energy consumption to better fit into the available renewable energy. If a geographically distributed datacenter is the target of implementation, the aim is to migrate jobs towards datacenters locations with higher level of renewable energy availability.

[3] presents a novel cooperation scheme between smart city and datacenters. This study results from DC4Cities approach project. Its aim is to reorganize workload in order to match the shape of renewable energy supply curve and minimize brown energy consumption, by predicting future renewable energy availability. As a result, the percentage of renewable energy consumed by the data centre is increased up to 23.25% compared to non-smart scheduler. T. Cioara et al. present at [4] a flexible mechanism for shifting the DC's energy demand profile from time intervals with limited renewable energy production to time intervals when spikes of production are predicted. A daily action plan is built one day ahead, to be corrected every four hours, and at last a check is made every 15 minutes. The workload is considered as "real-time" and "delay-tolerant". For 24 hours of simulation, the results show 12% renewable energy usage increase, which is translated into 2845 kg of CO2 reduction. While the mentioned works [3] and [4] are implemented in simulators the authors have built in their own, we have used a well-known simulator called CloudSim, which still lacks this algorithm. Also, the workload we are based on resembles Google's trace file, as described in Section 3.2.

In contrast to the above case, [5], [6] and [7] represent studies where the scheduling algorithm is implemented in a real physical infrastructure. A real Datacenter of 16 servers is built from researchers at Rutgers University. The authors present at [5] GreenHadoop, a MapReduce framework for a datacenter powered by a photovoltaic solar array and the electrical grid as a backup. It aims an increase of green energy consumption and decrease of electricity cost in comparison with Hadoop. The results show an increase of green energy consumption by up to 31% and decrease of electricity cost by up to 39%, compared to Hadoop. Over the same Hardware, the authors present at [6] and [7] GreenSwitch and GreenSlot. GreenSlot is a parallel batch job scheduler, which predicts the amount of solar energy that will be available in the near future, and schedules the workload to maximize the green energy consumption while meeting the jobs' deadlines. If grid energy must be used to avoid deadline violations, the scheduler selects times when it is cheap. Two types of workload, each of them categorized into deferrable and non-deferrable, are run for 24 hours of simulation time. GreenSwitch [7] is a model-based approach for dynamically scheduling the workload and selecting the source of energy to supply the selected hardware platform (called Parasol).

Studies like [8] and [9] address scheduling jobs over geographically distributed Datacenters in order to exploit maximum renewable energy capacities. Zhang et al. propose GreenWare [8], a novel middleware system based on an efficient request dispatching algorithm. It aims to maximize the percentage of renewable energy used to power a network of distributed dc's, within cost budget constraints of the Internet service operator. Using a 2 months trace file representing Wikipedia web requests workload, simulation is run over 4 distributed homogeneous Datacenters. As a result of GreenWare, percentage of renewable usage increased significantly, under cost limits. Likely, authors at [9] achieve an increase of renewable energy usage, considering best cooling conditions of datacenters' locations.

## III. SYSTEM SETUP

In this paragraph, we will describe the main factors that affect the datacenter system. First, datacenter parameters and workload characteristics, as configured for simulation, are outlined. Then, we present renewable energy data belonging to Albania weather conditions. Section 3.4 gives basic knowledge about the simulator we used to implement the algorithm and run the experiments followed by implementation details of the workload postpone algorithm. The algorithm is explained in details at the fifth subsection.

### 3.1 Datacenter

Datacenter represents the processing entity in our system. It runs the workload and consumes energy, which we track during 24 hours of simulations. Datacenter parameters are chosen based on similar experimental studies in the field of energy consumption in datacenters and typical datacenter size in Albania.

To run the simulation we configured the number of hosts equal to 100 and the number of virtual machines running over hosts equal to 200. This means, 2 virtual machines run for every host. The host type is HP ProLiant ML110 G5, Xeon 3075, processing capacity 2660 MHz, 2 cores and RAM of 4GB. TABLE 1 shows the detailed parameters for the datacenter configuration in CloudSim.

**Table 1:** Datacenter detailed parameters

| | Nr. | CPU | RAM | MIPS | Model |
|---|---|---|---|---|---|
| **Host** | 100 | 2 cores | 4 GB | 2660 | Xen 2660Mhz |
| **VM** | 200 | 1 core | 2 GB | 2660 | |

### 3.2 Workload

The workload chosen for the experiments represent a synthetic reproduction of a Google workload, scaled over our own simulating datacenter parameters. A Google trace file was published in 2011, giving detailed information of 12.000 Google servers traffic over 29 days, processing various types of applications. This workload data are studied in order to know its characteristics. The main findings of studies [10], [11] and [12] are used in our workload in order to produce patterns that resemble to the Google workload.

As such, we configure the following workload parameters for our study: total number of jobs, their length, deadline, resource requirements and inter-arrival time. The chosen number of jobs is 400, where 200 of them are short, 150 are medium and 50 are long. The length of short jobs varies from 5 to 7 minutes, medium jobs from 25 to 50 minutes and long jobs from 100 to 300 minutes. The jobs length is generated through Poisson distribution. Deadline is another parameter we set, which is the limit of time it can pass till the job is fully completed. Based on bibliography, we categorize jobs into three types of deadline: loose, medium and urgent. 130 of short jobs have loose deadline, which means they are too tolerant over postpone in a later moment to be run, 50 of short jobs have medium deadline and 20 are urgent. Out of 150 medium length jobs, 100 have loose deadline and 50 have medium deadline. Meanwhile, all long jobs have loose deadline. Loose, medium and urgent deadline is set in proportion to jobs length. Regarding resource requirements, half of short jobs require an average of 25% of CPU usage and other half requires 50% of CPU. 50 out of 150 medium jobs require 25% CPU and 100 of them need an average of 50% CPU. While long jobs needs to use an average of 80% CPU.

The inter-arrival time is set to every 5 minutes for short jobs, every 30 minutes for medium length jobs and every hour.

### 3.3 Renewable Energy

In our study, we used solar energy to represent renewable energy. A. Maraj present a study regarding solar energy in Tirana [13]. We acquire the solar energy data from the results of this study. The parameters are provided from the database built through the utilization of a data collecting system, which is installed on behalf of the Department of Energy, Faculty of Mechanical Engineering, Polytechnic University of Tirana. Solar power irradiance on a 45° tilted 1 m2 solar panel, installed over the terrace of the central building of this University, has been collected, providing data for every hour of its daily operation. We consider two days as a model: typical clear summer day and typical cloudy summer day. The specific dates are July 16, 2010 and July 26, 2010 respectively. Further details on solar panel specifications and results of the study are explained from A. Maraj's article [13]. Results of the available solar energy are shown in Fig. 1 and Fig. 2. Horizontal axis shows 288 5-minutes intervals of one day and vertical axis represents Energy produced in Wh.

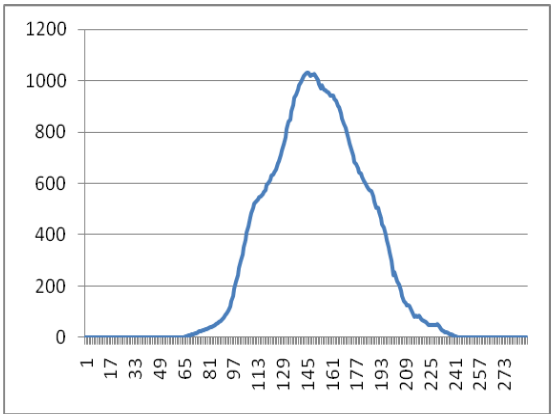


**Figure 1:** Available solar energy during a typical clear summer day in Albania, generated from $1m^2$ solar panel

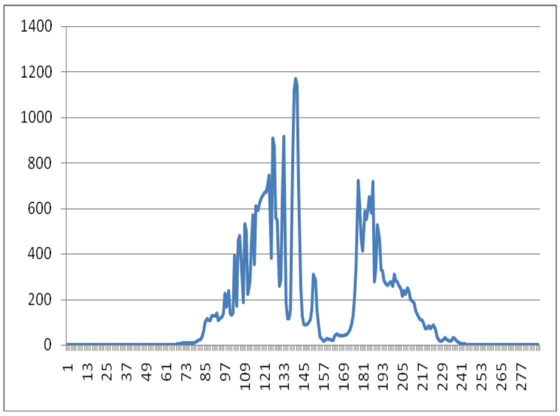


**Figure 2:** Available solar energy during a cloudy summer day in Albania, generated from $1m^2$ solar panel

### 3.4 Cloudsim

CloudSim is an extensible simulation toolkit that enables modeling and simulation of Cloud computing systems and application provisioning environments. The CloudSim toolkit supports both system and behavior modeling of Cloud system components such as data centers, virtual machines (VMs) and resource provisioning policies.

Its main functional entities include:

- Hosts: physical machines where the jobs are to be executed
- Virtual machines: virtual entities running over real physical entities
- Cloudlets: representing the workload or the jobs to be executed in the datacenter
- Broker: a scheduler which allocates virtual machines to hosts and cloudlets to virtual machines.

CloudSim is chosen as a simulator because of its high rate in reviews of the energy efficiency in datacenter field, 7 years among researchers and still being widely used, open source code and a rich forum of programmers and researchers.

The proposed algorithm is implemented in CloudSim as a workload scheduling mechanism, evaluating and changing accordingly the time when the cloudlet is allocated to virtual machines. Further details on the algorithm are given in the following subsection.

### 3.5 Proposed Algorithm

The algorithm we propose for better managing the workload in terms of higher leveraging of available renewable energy is based in the following steps.

1. New job arrives
2. Is it urgent?
3. If yes, send it to the broker to allocate virtual machine to it, ready for running.
4. If not, go to step 5
5. Does the job arrive in a time when renewable is increasing?
6. If yes go to step 7, if not go to step 12
7. The job is short?
8. If yes, postpone by its length ***t_new = (t_arrival + short_job_ length)***
9. If not, is the job medium length?
10. If yes, postpone to the average time between t_arrival and job's deadline ***t_new = [t_arrival + (deadline – t_arrival)/2]***
11. If not, postpone at its allowed maximum ***t_new = (t_arrival + deadline – 1.2*long_job_length )***
12. Job has arrived when renewable energy is decreasing. Is the job short?
13. If yes, postpone it to maximum time allowed ***t_new = [t_arrival + deadline – 1.1* short_job_ length]***
14. If not, is it medium length job?
15. If yes, postpone to the average time between t_arrival and job's deadline ***t_new = [t_arrival + (deadline – t_arrival)/2]***
16. If not, then it's long job, run immediately, send to the broker so that it allocates virtual machine as the job requires.

Basically, the code is divided in two sections, testing if the available renewable energy is increasing or decreasing. In each case, the behaviour will be different. After testing the urgency of the arrived job, the algorithm decides to run it if it's urgent or postpone if it's not urgent. The amount of time it will be postponed dpends on renewable energy forecast for next period of time, equal to length of the job. If it's an increasing period, than the job is postponed to the next time period, as long as it doesn't violate its desired quality of service. Job's deadline is the limiting factor for the postpone process. Otherwise, if it's a decreasing period, the behaviour will be contrary to the previous one described above. Short jobs will be postponed at their maximum, as they require less processing resources, while the long jobs are immediately run in order to use the available solar energy, as step 16 shows.

## IV. EXPERIMENTS AND RESULTS

In this section, we describe the experiments which are run in the simulator, aiming to compare datacenter's energy consumption through 24 hours between three scenarios. First, energy consumption is measured as it's offered by default from the CloudSim simulator, without implementing the proposed algorithm. In the second scenario, datacenter energy consumption is estimated after implementing the proposed algorithm for postponing the workload in order to match the available solar energy. A clear summer day weather data is chosen for input solar energy in this scenario. The third scenario, in contrast to scenario 2, uses a cloudy summer day weather data as input for solar energy.

For the first scenario, the energy consumed by the the datacenter through 24 hours is estimated from CloudSim as a total of 125 kWh. Fig. 3 illustrates datacenter's energy consumption fluctuating as workload intensity and resource requirements vary. Horizontal axis illustrates 24 hours, while the vertical axis illustrates the energy consumption in Wh.

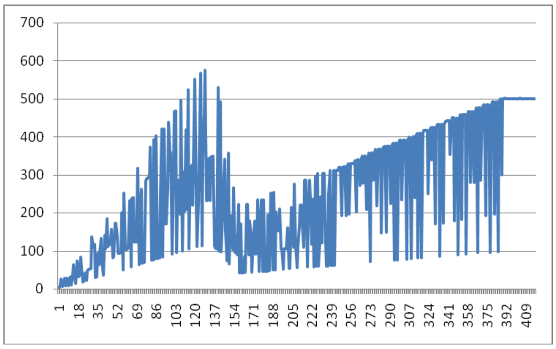


**Figure 3:** Scenario 1, energy consumption through 24 hours simulation, new algorithm not implemented

In order to achieve a case study of 75% of datacenter energy need supplied by solar energy, it means a total of 94kWh of solar energy is required to be produced daily. For this reason, based on the fact that 1 $m^2$ solar panel produces 3.5kWh per day, collected from weather data, we calculate that 27 $m^2$ of solar panels are needed to be used to achieve 75% of the configured datacenter's energy consumption with renewable energy. This is the input for renewable energy during the simulations we run in our experiments.

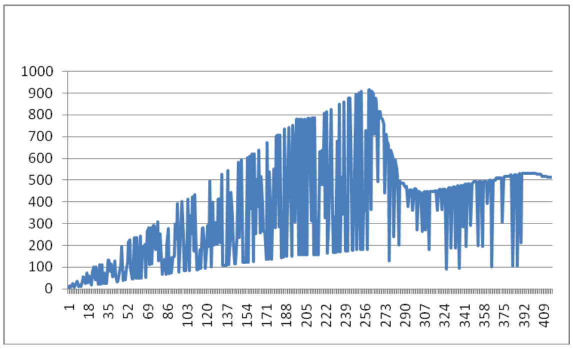


**Figure 4:** Scenario 2, energy consumption through 24 hours simulation, new algorithm implemented, clear day renewable energy as input

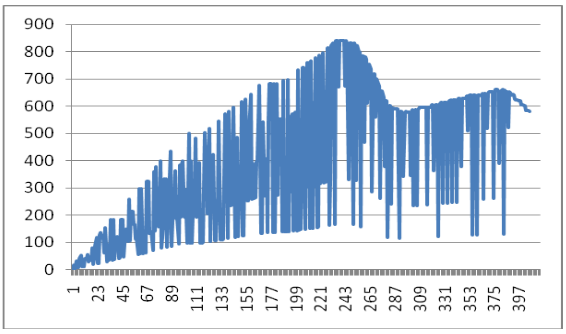


**Figure 5:** Scenario 3, energy consumption through 24 hours simulation, new algorithm implemented, cloudy day renewable energy as input

As Fig. 4 and Fig. 5 illustrate, in both scenarios, workload postponing provides energy consumption which resembles to the renewable energy availability curve. Comparing the results between available and used solar energy, it is calculated that our algorithm achieves up to 17% higher utilization of produced solar energy.

## V. CONCLUSIONS

In our paper we address the issue of supplying datacenters with renewable energy sources, which poses a new challenge because of its high variability. Managing the workload, by urgently running or postponing arrived jobs, is the main direction we focus on. We propose an algorithm aiming to match the energy consumption to the available renewable energy, in order to maximize renewable energy usage. We implemented the algorithm in CloudSim simulator and run experiments to estimate it. To do so, energy consumption over time is compared in three different scenarios: no postpone algorithm is implemented and proposed algorithm is implemented with two different solar energy inputs, clear and cloudy summer days. The results of the experiments show that workload management and scheduling is a promising direction towards greener datacenters. Comparing the results for the estimated energy consumption, with and without the proposed algorithm, it is clearly illustrated that the mechanisms helps in higher utilization of renewable energy, up to 17%.

The study is limited to specific type of workload which is composed by set of jobs having loose deadline. This allows jobs to be postponed in order to maximally exploit available renewable energy.

Another limitation of this study is time period taken in consideration for study. We consider only solar energy values during typical summer clear and cloudy days. However, the proposed algorithm must be further developed for adapting to dynamic weather changes over a day, including more variable solar energy during one day and considering winter days also.

Another direction to be explored further would be integrating other sources of energy as suppliers for the datacenter i.e wind energy. That would compensate the dropping of solar energy, resulting in smoother total renewable energy.

## ACKNOWLEDGEMENTS

This research was partially supported by Cost Project, NESUS, 2016. Thankful to IRIT staff, University Paul Sabatier, for their support and valuable comments. Grateful to Ardit Meti for his assistance.

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