Dynamic Virtual Machine Migration using Ensemble Regressor based controller to reduce the Green Energy wastage and Optimal Utilization of Resources towards Green Computing

MSc Research Project
Cloud Computing

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MSc Project Submission Sheet

School of Computing

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Student ID:	19226331		
Programme:	Cloud Computing	**Year:**	2022
Module:	MSc Research Project		
Supervisor:	Sean Heeney		
Submission Due Date:	16/09/2022		
Project Title:	Dynamic Virtual Machine Migration using Ensemble Regressor based controller to reduce the Green energy wastage and Optimal Utilization of Resources towards Green Computing.		
Word Count:	7489	**Page Count:**	25

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Dynamic Virtual Machine Migration using Ensemble Regressor based controller to reduce the Green Energy wastage and Optimal Utilization of Resources towards Green Computing

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Abstract

In the current era, the cloud has emerged as the main source for providing services related to storage, computation, and networking solutions. To provide hassle-free services to the users, various data centers in different regions of the world are established by cloud providers. These data center consumes a high amount of electricity and emits a high amount of carbon. Due to Environmental issues, Govt strict policies, and saving energy costs, many cloud providers are switching toward the green computing solution. Green Computing Solution motivates to utilize the renewable source of energy for power generation. With the dependency on the renewable source of energy such as Solar, Wind, and thermal energy, there are certain challenges associated such as Dynamic load generation by the users, Weather unpredictability, etc. To solve such challenges, in this research, we are proposing an AI-based controller for forecasting the energy to efficiently distribute the load and utilization of resources. After a certain set of experiments with multiple machine learning algorithms such as Linear regressor, Support vector regressor, Bayesian regression, and Ensemble regressor over the simulated cloud computing environment. We have achieved the optimal outcomes from the Ensemble regressor method, which helps to reduce the green energy wastage and provides accurate prediction to perform Virtual machine migration among the different sets of clusters.

1 Introduction

The rapid advancement of technology has redesigned human life and nature in a way that is truly unforgettable. On such attainment, cloud computing has gained a higher position. Previously, it has witnessed tremendous growth over time with the sudden climate changes, and the reduced emission rate due to energy use has gained more attention in recent years (Ahuja & Muthiah, 2018). However, there is a vigorous increase in the energy demand as well. The increased global awareness has reduced the emission of greenhouse gases and thereby attaining a healthy environment. Green computing here aims to bring awareness into action by reducing energy consumption and promoting the reuse of that energy (renewable energy) and additionally minimizing the huge carbon emission for both the benefit of mankind and the environment. To be specific data centers of cloud use an enormous amount of non-renewable energy source and deliberately promotes huge carbon emissions.

The increasing demand for cloud infrastructure has deduced the main cause of huge energy usage. The quest for consumption of power has significantly increased the emission rate of carbon or carbon footprint that has a harmful impact on the environment. In fact, carbon emission is a common aspect in every IT company or in those firms where there is huge advancement in technologies and modernization. The exponential growth in data centers to heightened numbers with paramount of servers as well as other infrastructures bears the responsibility of maximizing the energy consumption. Hence, it is admissible to attain a safe and healthy environment and thereby increase green awareness by advancing towards integration of reliable infrastructure with cloud computing, preferably green computing.

Green cloud computing indicates the practices or otherwise the approaches where the use of advanced technologies for example computing & other information technology (IT) resources bears meaning to environment-friendly advancement. It refers to the study to design, create, and integrate digital equipment to reduce carbon emissions, thereby offering a safe and sustainable environment. The classification of major global cloud service providers includes Microsoft, Google & AWS has strategically incorporated renewable sources of energy to operate the data centers in order to deploy the specific advantage of Green Computing. According to research which is earlier conducted by Google, "Lawrence Berkeley National Laboratory" and "North-western University", have discovered the benefit of shift in common software applications that are used by nearly 86 million people in US pertaining to cloud can reduce the energy consumption by about 87% respectively. Moreover, the same report has emphasized the fact that due to the shift, the widespread use of cloud computing has resulted in reduction of energy consumption by data centers up to 31% between 2010 - 2020. To minimize the cloud computing effect on environment, there is a requirement for energy-efficient technologies. These methods in turn can help in energy conservation as well as promote feasible cost structure. "Green cloud computing" in looked deeply, is an approach to deploy "green information technology" which has a potential to reduce energy usage. Thus, it plays an important role to improvise the future aspects of cloud computing in business.

Now coming to the part of development of green computing, a deep and profuse understanding of the contribution of data centers in adopting the system is mandatory. More specifically, it is necessary to acknowledge what is the advancement done by Cloud providers in establishing Green Computing. Also, it is admissible to prefer the use of renewable sources of energy rather than the use of non-renewable sources. Thus, all these attributions are the basics of advancing towards creating a safe and healthy environment with the usability of cloud information technologies. Nano Data-Centers have outperformed conventional server centers through productivity. It assists in reducing the heat dissipation costs, providing the large service areas as well as self-scalable. Frequency scaling and/or "dynamic voltage frequency scaling" defines an approach that enables the reduction of power & energy use. The attainment of this strategy can significantly minimize energy consumption with an impact prevalent on resource usage. Virtualization has vehemently quantified the availability of system resources by maintaining eco-friendly nature. It enables the improved monitoring process with efficient resource allocation and management. Additionally, it enhances the maximization of capacities of server groups to share the resource overall. Since there is wide dependency of business on cloud services, approach to new IT applications, as well as practices that promote sustainable environment is a frequent approach to create a safe and compatible environment. Hence, the admissibility to promote green cloud computing is an adamant step to devise better use of cloud computing with improved operations that can improvise energy consumption behavior and reduce carbon emissions.

In this research, to achieve the green computing objectives we will be utilizing advanced technologies such as Machine learning algorithms to pre-calculate the energy generation with renewable sources of energy. As predicting the energy generation is a regression problem, algorithms such as linear regression, Bayes regression, support vector regression, and ensemble regressor will be implemented in cloud computing environment and performance will evaluate. To evaluate the model performance over cloud architecture metrics such green energy wastage and prediction accuracy will be calculated.

1.1 Research Objective

The contribution of cloud computing, particularly green cloud computing is the main discussable topic of this study. The profuse understanding of technology implementation to reduce green energy wastage and optimal utilization of resources along with minimization of Virtual machine migrations using AI-based algorithms is the main objective of this research. Hence, the main contribution of this study has aimed at investigating the use of renewable sources of energy to promote sustainable environment and optimally reduce the consumption of non-renewable energy resources.

1.2 Research Questions

- How the AI-based algorithms can help to reduce the green energy wastage and virtual machine migration to achieve the green computing objectives?
- Which algorithm can accurately forecast the energy generation from renewable sources and to what extent the Ensemble regressor prediction can help to maximize the utilization of Renewable sources of energy?

1.3 Conclusion

The comprehension of knowledge on green cloud computing promotes an understanding of energy efficiency which is completely based on renewable energy usage. Green Computing (GC) is a new concept in today’s world that not only modifies the energy usage by data centers providing cloud services but also enable to reduce carbon emissions and maximize usage of energy generated through renewable source of energy at a reasonable rate. This acknowledgment is the main understanding of this chapter or in general of this study where research untaken a new exploratory path to contour all possible implementations of advanced technologies toward green computing. Hence, it can be concluded, through this chapter the enhancement and engagement of cloud infrastructure have been possibly attained which would be further elaborated with different specifications in the next chapter for better attainment of environment sustainability via green cloud computing.

2 Related Work

2.1 Brief Overview of Cloud Computing

Cloud Computing has been considered the most proficient computation paradigm being observed in the field of information technology in recent times (Khattar et al., 2019). However, it is necessary for the data centers to host their cloud services unreasonably demanding electrical energy & releasing harmful greenhouse gases that polluted the environment. Thus, the assurance of an active and sustainable future can only be retained through energy efficiency within cloud computing. The framework for resource allocation under Cloud Infrastructure for energy efficiency is gaining importance in recent decades (Thein et al., 2020; Bermejo et al., 2016). In fact, prior to these engaging thoughts, it became a constant challenge with huge energy consumption by Cloud computing systems (Bermejo et al., 2016). Thus, the efficient consumption of energy and minimization of carbon emissions become a major priority by cloud service providers.

The architect of cloud systems in recent times has designed proper locations for the data centers and remodeled their system. Meanwhile, the efficient use of technology and resource management is taken into consideration under two saturated levels: “physical machine level” and “overall system level” (Khattar et al., 2019). Under such consideration, edge computing gained importance to extend the “quality of services” (QoS) for cloud computing while provisioning the delay guarantee with an aim to delay-sensitive applications (Guo et al., 2019). Hence, all these implementations have been considered to achieve systemic progress in energy-efficient cloud computing through appropriate consumption of renewable energy resources and collaterally minimizing carbon footprints through versatile cloud computing infrastructure.

2.2 Green Cloud Computing and its Practices

Since the emergence of cloud computing, the deployment of the interface in meeting business goals has been carried out successfully. Over the years, the cloud service providers are overwhelmed with the growth they achieved while disseminating knowledge about various needs introduced by business sectors. Briefly, it has gained importance among different industries due to its advanced concept and extensive operational advantage. However, the attainment has severely affected due to high energy consumption and depletion of environment due to greenhouse gas emissions which then saturated with a new concept. This new concept thus derived as Green Computing where energy efficiency to minimize sudden climatic change and carbon emissions are the prime factors (Ahuja & Muthiah, 2018).

The rapid advancement of information technology has reflected the tremendous use of cloud services via data centers. Meanwhile, the reduction in consumption of computational power within the data centers becomes a challenging issue in this current era. In fact, various researches have been conducted to improve the system of cloud computing through efficient energy consumption. Herein, the power or energy consumption has a direct link to resource allocation for different tasks (Mishra et al., 2017). Thus, it is a mandatory factor to study the power consumption in cloud computing environments adhered to various services and hence designed the concept of green computing. One of the studies conducted by (Jeba et al., 2021) has presented an optimized framework for energy efficiency. This framework is based on the "dynamic resource scheduling" (DRS) for the Virtual Machine Migration (VM) within the data centers of the cloud. There is a huge quantification of cloud data-centers across the world which tremendously consumes huge amount of energy and correspondingly releases carbon dioxide (CO2) in the atmosphere. This release of CO2 not only causes pollution in the environment but also become a threat to humans. Thus, this above-mentioned study has introduced green cloud computing via virtual machine migration that can appropriately allocate resources for users to perform their tasks.

The functionality statement while gaining attention as an intermediate between the tenants & the cloud providers, the brokers that introduces cloud service (CSB) effectively bring out great benefit for the cloud market (Qiu et al., 2018). These brokers usually buy resources from the providers at low prices and correspondingly sell the cloud service-oriented resources to the buyers (tenants) at high prices. In the meantime, to increase self-profit, the CSB (server) forward the tenants' request to the cloud service providers which in turn waste enough energy resources. To say the least, this intermediary has caused a great burden to cloud service enhancement and more impact falls with the increased energy costs. Thus, the frequent need for energy efficiency optimization is a mandatory step (Qiu et al., 2018, Raja, 2021). In overall confrontation, the arena of green cloud computing through proper implementation of renewable energy resources and dynamic approach to approved artificial intelligence, algorithms and the IoT-based infrastructure has been recognized as an eminent practice which has advertently balanced power consumption and incredible resource allocation to tasks performed by users worldwide.

Virtualization technology promotes convenience towards improvising resource utilization along with high throughput of the cloud services (Shu et al., 2021). But the main issue arises with the randomness shown in task arrival, with immense coupling among resource load imbalancing & node heterogeneity, huge power consumption for computing, and the other factors which cause hindrance in optimization of energy consumption as well as cost reduction for existing technologies. The consequent failure in task scheduling is difficult to eliminate which thereby decreases the performance of cloud computing at a dramatic level. Thus, while prioritizing optimization in task scheduling and energy consumption, the response with strong agile method is a significant approach to understanding both the cases accustomed to data centers (Shu et al., 2021). The optimization of Agile response is also noted with the involvement of suitable techniques. With the understanding of the reason for task failure, the efficient advancement with this algorithm can modulate the model response, exploring the probability of density function while reinforcing the outflow of "task request queue" and request for timeout for avoiding network congestion. As per the result obtained for this proposed algorithm, it shows both stability & efficiency in task scheduling while improving the complete throughput of this cloud computing system.

2.3 AI-assisted approach in Green Cloud Computing

Cloud computing excels with an important role in modern society & hereby enables various applications secluded from building infrastructure to engage in social media. In the confinement of such a system, it is necessary for them to cope with the varying load as well as evolve energy usage while reflecting social interactions & the dependency on automated computing system with proper guarantee of "quality of services" (QoS) (Gill et al., 2019). The rising complexities with the demand for evolving applications of computing the need of identifying key technologies become mandatory to promote future applications. On such approach, the paradigms of triple influence of blockchain, internet of things (IoT), and artificial intelligence (AI) become a prominent step to improvise future systems of cloud computing.

With the extensive growth of the IP network, the immense cloud computing advent as well as the rapid progress with wireless communication systems has enhanced the demand for data traffic in today's world (Etengu et al., 2020). On a consequent note, it is necessary for service providers to deploy an efficient & intelligent network solution that can accommodate this increased traffic demands while easing capacity pressure within the network infrastructure. While contemplating all the operations, it is equally important for the vendors to develop optimized energy-efficient networks that can reduce the cost structure and eliminate carbon footprint. Thus, in all these advents, Software-defined networking system (SDN) can be a progressive solution but the main issue here is with its deployment which cannot be achieved in the short-term. Thus, the hybrid approach of SDN with AI classifications such as machine learning or deep learning to manage network traffic can be a real-time solution (Etengu et al., 2020). In most research papers, this hybrid method has been explored to acknowledge the review of optimization in energy-efficient global routing as well as load balancing. Since such system can be a better configuration to reduce global network-energy-consumption & improvise link performance, a considerate need for more research is stimulation to develop further research insights on this current progress.

2.4 Load Balancing and Cloud Resource Allocation by various Algorithms

The framework of cloud computing contours a wide variety of components initiating from virtual machines, hosts of data-centers, and servers (brokerage). This broker often searches for reliable cloudlet-assisted virtual machines to execute. However, vulnerability in network can be a challenge that tremendously overburdens the clod framework. Thus, a proposed approach with *ant colony optimization* (ACO) has been introduced which promotes optimized virtual machine migration that can reduce both execution time & energy consumption (Ghani Alyouzbaki & Al-Rawi, 2021). In fact, it can be a better approach to load balancing and resource scheduling in cloud with effective execution time as compared to previously developed “three-threshold energy saving algorithms” (TESA). In fact, various algorithms have been used to mitigate the issues of load imbalance, inefficient resource allocation for tasks, huge energy consumption, etc (Lu & Sun, 2017; Hou & Zhao, 1 C.E.; Karthiban & Raj, 2020). A study conducted by (Hou & Zhao, 1 C.E.) explained a fusion approach of algorithm for resource scheduling & load balancing with deep learning method. His results give a comparable note with optimal ability to reduce energy consumption by data centers.

The explosion in data volumes that are generated with increased applications has impacted the evolutionary pace of digital infrastructure confined to data analytics & machine learning. While data analytics plays an important role in cloud infrastructure, the rapid progress in IoT-based infrastructure has motioned the development of edge analytics (Rosendo et al., 2022). However, the reproducibility of cloud infrastructure and IoT advancement had irrevocably extended energy usage with immense task resource allocation. Hence, this consumption has induced a huge burden on ecosystem along with the intensified carbon footprint generation. This is where green computing comes into action. However, the cost of energy & low efficiency become real issues in proper meeting of the green concept. Therefore, the progression to novel algorithm of “energy-efficient load-balancing” in response to global optimization can be a better approach (Lu & Sun, 2017).

2.5 Autoencoder-based Cloud Resource Utilization Approach

The continuous growth of cloud services should be enabled with smart & holistic strategies for resource scheduling (Ikhlasse et al., 2022). In such formulation, the approach to deploy efficient DL-based technologies to restrict chaotic traffics in cloud services can be solvable method. Toward enabling efficient scheduling and rightsizing cloud instances, the new “bidirectional gated recurrent unit predictor” comprising “Stacked Denoising Autoendocoders” has simultaneously forecasted effective utilization of internal storage, memory, and CPU (Ikhlasse et al., 2022). Based on the result obtained with this proposed predictor shows a subsequent decrease in average power consumption by 5% in comparison to previous models.

2.6 Green Computing with Renewable Energy Resource

The meeting of intensified needs of cloud computing by users has increased tremendous energy usage and frequent carbon emissions by data centers in recent times. To cut-off, this peak consumption of energy or smoothen the intermittent power generation for data centers various researchers has proposed distinct methods for convenience. But, a constant lacking in joint-energy management associated with peak shaving & use of renewable energy resource harvest in datacentres is observed. Hence, the study conducted by (Liu et al., 2016) has introduced a schemed model for power management, i.e., RE-UPS that enunciates renewable energy use in data centers. This model is totally based on energy storage distribution architecture along with existing infrastructure of UPS in data centers. The experimental result shown through RE-UPS promotes energy back up with 28% capacity, extended battery life by 42%, hike in green energy usage by 78%, and consequent decrease in workload and performance degradation by nearly 13% (Liu et al., 2016).

2.7 Approaches to Virtual Machine (VM) Migration Optimization Algorithm

Cloud computing enhances dynamic promotion of the server abilities which become a scalable virtualized service for end-users. However, on certain scalable services, the waste energy resource generation becomes massive in amount that being hosted by data centers resulting in huge operational costs & carbon footprints (Y. Xu & Abnoosian, 2022). On availing cloud services, virtualization encompasses the main feature while delivering physical resources typically enhanced by the virtual machine. Hence, in such advent, it is necessary to improvise the power consumption by virtual machines. It is one of the areas of research in cloud computing that has been evaluated by many researchers in their studies. Energy consumption and VM scheduling are two key aspects of cloud computing that have faced critical challenges (Y. Xu & Abnoosian, 2022; X. Xu et al., 2019). To solve both issues, an approach with *genetic algorithm* & *particle swarm optimization* shows better results with an average improvement of 23.19% (Y. Xu & Abnoosian, 2022). Another study proposed by (X. Xu et al., 2019), shows an approach for VM scheduling with an algorithm enhanced with gravitation effect, named VMSAGE. Based on the study observation, it is effective in energy efficiency optimization in cloud computing. Further, the method is compared with existing "dynamic voltage and frequency scaling" (DVFS algorithm and other heuristic methods. The experimental result obtained therein shows 10-20 percent optimized consumption of energy resources. Thus, the overall result stated with the new implementations of algorithms there is a significant reduction in energy consumption as well as execution time for VM.

2.8 Conclusion

The elaboration of various techniques to enhance cloud computing services with optimized energy consumption, resource allocation, and scheduling has been established in this chapter. Throughout the discussion, a common establishment of green computing is the main factor that has been recognized with productive method implementations. Thus, it can be concluded that this chapter has developed an understanding of the issues being aligned that restricts the efficient modulation of cloud computing system and hence induce an engagement by method implementation to mitigate the issues which thereby can promote a green computing infrastructure.

3 Research Methodology

Due to the surge in the demand for cloud, a greater number of datacentres are being developed by organizations to provide the services to their customers seamlessly. There is enormous number of cloud servers/clusters available in a datacentre, which requires a high amount of energy sources/electricity to process the user-generated requests. To meet the green computing criteria, these organizations are using renewable sources of energy such as Solar energy, Wind energy, Thermal Energy, Tidal Energy, etc for power generation. However, dependency on renewable sources of energy as a power source is very unpredictable and the amount of power/energy generation highly depends on the weather patterns such as Sunlight, temperature, lunar cycles, etc. However, it has been identified that weather patterns in the different regions are found to be cyclic in nature with some degree of randomness. To simulate such conditions, we considered a cloud architecture composed of multiple clusters spanned across multiple geographical regions. Where each region has its own energy production system depending upon the climatic conditions, this simulates the real-world behaviour of solar, wind, and hydro energy production units. For efficient utilization of green energy, we require a smart load balancing algorithm that allocates/de-allocate the load/resources to the cluster as per the energy availability. Therefore, in this work we have proposed a Green Computing cloud computing architecture that utilizes the machine learning algorithm for predicting the future energy and based on that load on the cluster are assigned or VMS are migrated. The overall architecture of the Green Computing-based cloud environment is shown in Figure 1. Our proposed architecture consists of a different set of components, the explanation of each component is explained in further subsections.

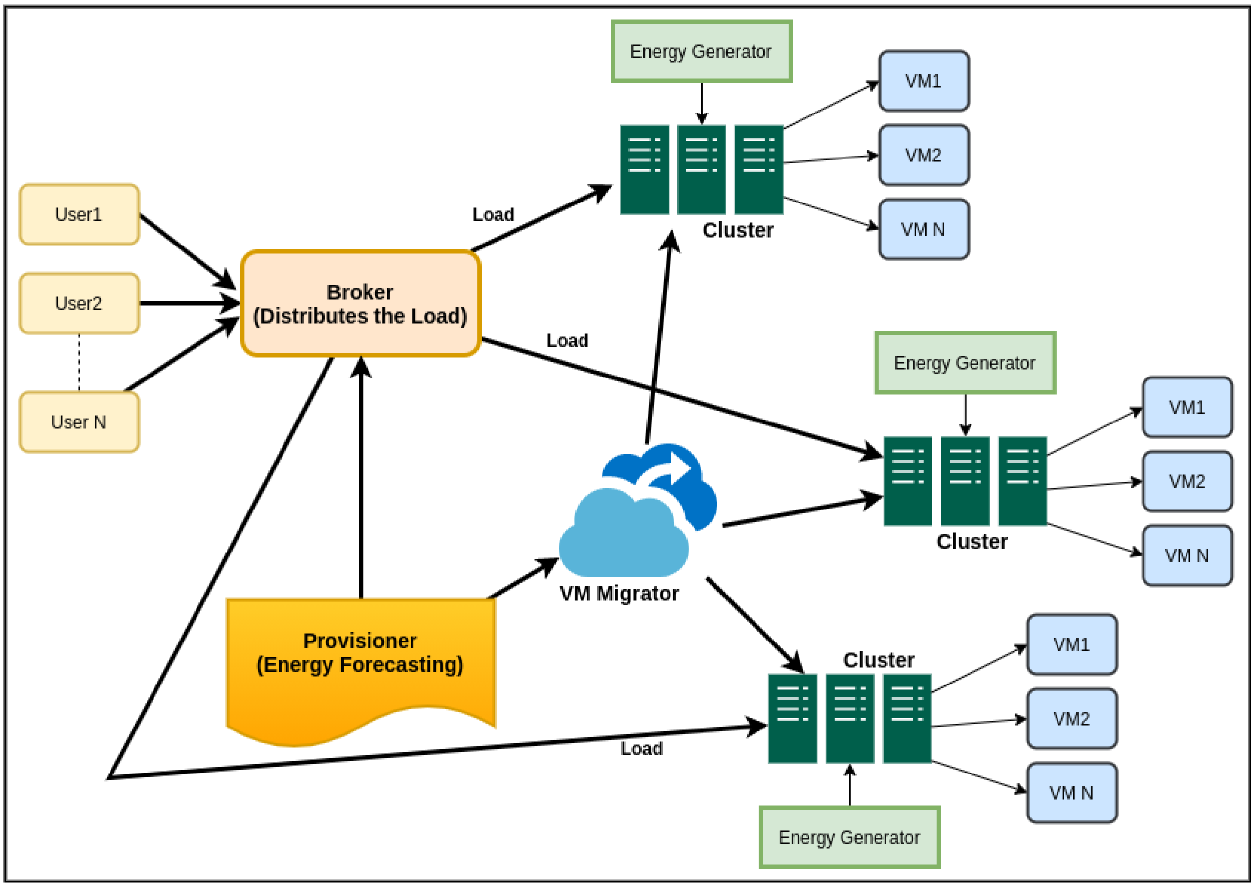

Figure 1: Green Computing based Cloud Architecture (using AI Techniques)

3.1 Users / Data Generation

User is the first component of our architecture, which is available on the client-side. Users can be any client machine sending a request to the cloud server for processing. Multiple users at a same time can also send the request to the cloud server. Each request of the user is associated with some load, which needs to be processed by the cloud system. On further analysis, User behaviour is also found to be cyclic in nature, sometimes the number of requests is very high, and sometimes, found to be very minimal. User and Cloud brokers are interconnected with each via internet connections, where users send all the requests to broker component.

3.2 Broker

The broker receives the requests from multiple users, this request generates a specific load on the cloud server. Broker is responsible for spreading the load to multiple clusters. However, the criteria for amount of distribution of load is based on the energy forecasting performed by Provisioner. As per the energy prediction, the broker spreads the load proportional to the availability of energy in cluster. Broker mainly acts as a channel, which broadcasts the loads based on forecasted energy of clusters.

3.3 Cluster

Cluster is the main component of system, which is used to process the load generated by the client. Cluster mainly utilizes the energy generated by renewable sources and load generated on cluster consumes a specific amount of energy to get processed. The power of cluster is divided across the multiple virtual machines, where number of virtual machines running in the cluster at a given time is directly proportional to the amount of energy available in the cluster. The Virtual machines associated with the cluster can be migrated from one cluster to another. As per the current architecture, our system consists of 3 clusters, where each cluster can have N number of virtual machines associated with it depending on the amount of energy generated. The overall capacity of each cluster is different from one another.

3.4 Provisioner

Provisioner is the most crucial component of the cloud computing architecture. It is directly associated with the energy generator sensors of all the clusters, where all the sensors provide their historical data of energy generation and current consumptions of energy by the cluster to the provisioner. Based on this data, provisioner forecasts the energy which is utilized by brokers and migrators in cloud computing architecture. Provisioner is a place, where the algorithms reside, a wrong prediction may lead to higher energy/resource wastage. Therefore, it is very necessary to choose an algorithm wisely. In order to identify the future energy forecast, traditional approaches may not work efficiently due to dynamic changing in workload and dependency on the weather. Therefore, in this work, we are utilizing the machine learning algorithm for forecasting the energy based on which the load on the cluster can be adjusted and VMs can be migrated. The algorithms used in this work are Support Vector Regressor, Linear regressor, Bayesian Regressor, and Ensemble Regressor. Among these algorithms, most optimal algorithm will be identified and used for following cloud computing architecture as shown in Figure 1. Provisioner can be also called the controller, as it controls the overall cloud system with energy forecasting.

3.5 Migrator

Migrator in our system is responsible for Placement of Virtual machines from one cluster to another. Migrator is associated with the provisioner of energy forecasting information. Based on this forecasting the VM migration is being performed among the clusters. Migration of VM is a computationally expensive task and requires a lot of bandwidth to migrate the VM from one cluster to another. Therefore, based on energy forecasting, migrator in advance can do virtual machine placements from one cluster to another.

4 Design Specification

In this section, the working mechanism of each implemented algorithm will be explained in detail. This chapter will discuss the design and architecture part of every algorithm. As forecasting of energy is a regression problem. All the regression algorithms such as Support Vector Regressor (SVR), Linear Regressor (LR), Bayesian Regressor (BR), and Ensemble Regressor will be explained in this chapter.

4.1 Linear Regressor

Linear regression is one of the machine learning algorithms in the supervised learning approach. It generally renders the regression task. Implementation of this algorithm estimates the best fit linear line between the independent variable and the dependent variable. Furthermore, there are two types of Linear Regressions which are namely Simple Linear Regression and Multiple Linear Regression depending on the independent variables. In Simple Linear Regression, there is only one single independent variable present through which the dependent variable relation had to be sought whereas, in Multiple Linear Regression, there is more than one independent variable present for which the dependent variable relation is sought. Although there is a certain condition for linear regression which is Linearity, Normality, Homoscedasticity, Independence or no multi-collinearity, no autocorrelation, and distributed error term. The term linearity states the linear dependence of the dependent variable on the independent variable whereas the term normality states the balanced distribution of the parameters. On the other hand, Homoscedasticity defines the constant variance of error terms, and the term Independence seeks no correlations among the parameters. Furthermore, it also stated that the error terms shall not be autocorrelated. The linear regression formula can be derived by following formula.

$$Y_i = f(X_i, \beta) + e_i$$

Where $Y_{i\ is}$ the dependent variable, X_i is the independent variable. B is unknown parameter and $e_{i\ is}$ the error term.

4.2 Support Vector Regressor

A support Vector Regressor is a type of Support Vector Machine that does the task of the regression. This regressor interprets the best fit hyperplane by evaluating the decision boundaries of given independent variables to dependent variables. The hyperplane is interpreted to consist of the greatest number of relational values. The greatest merit of this regressor is that it can efficiently handle the non-linear data relations, unlike the other regressors. It allows us to determine how much uncertainty is tolerated in the system and will select the best path to suit the data. The goal of this regressor is to minimize the parameters, especially the l2-norm of the correlation matrix rather than the disparities. Instead, we address the error word in the limitations, where we specify the standard deviation to be less than or equal to a defined margin, known as the maximum deviation or epsilon. To interpret the non-linear data relation, the regressor here uses the kernel trick. These kernels are of three types which are Linear Kernel, Polynomial Kernel, and Radial Basis Function. Furthermore, Figure 2, depicts the graph for the support vector regressor.

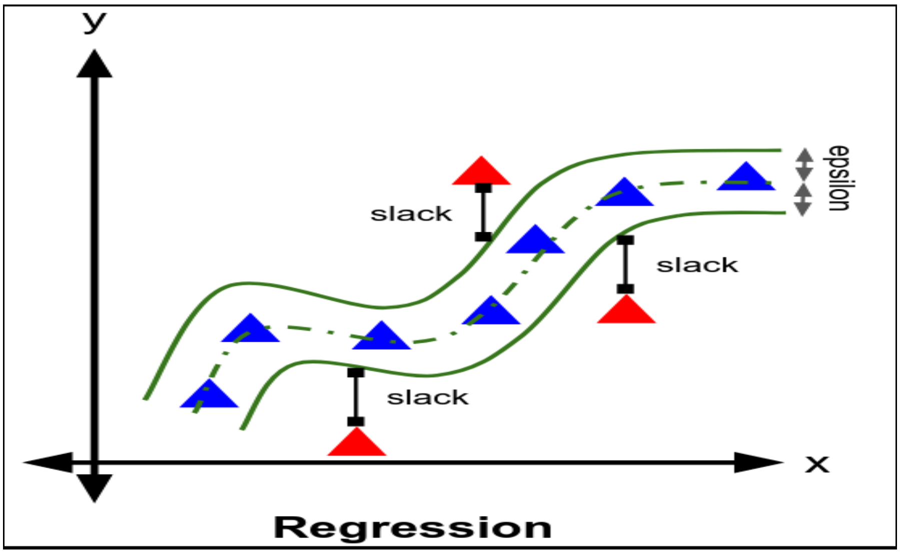

Figure 2 Support Vector Regression

4.3 Bayesian Regressor

Bayesian Regression is also one of the machine learning algorithms in the supervised learning approach. It is one of the sub-fields of Linear Regression that renders the regression task. The Bayesian utilizes the Bayes Theorem for the process. Furthermore, this algorithm interprets the posterior instead of the model parameters. Bayesian linear regression is a form of implicit modeling that uses the mean with one variable described by a linear combination of other parameters, to get the posterior distribution of the factor loadings and eventually enable out-of-sample forecasting of the regressor based on demonstrated multivariate regression principles. The primary merit of Bayesian regression over Linear Regression is its robustness and efficiency of the process for the minimal dataset. On the other side, this regression has certain demerits such as the time-consuming stature and inefficiency of the large set of data. The standard linear framework is the basic and most frequently used variation of this framework, in which specified variables are distributed Gaussian. The posterior may be solved numerically in this framework and under a certain set of prior probabilities for the parameters called conjugate priors. With more arbitrary priors, the posteriors must usually be estimated. Considering its final interpretation, the model obtains the prediction of complete posterior probability distribution rather than the model parameters.

4.4 Ensemble Regressor

Ensemble regressor is the combination of multiple regressor algorithms. Where the predictions of each machine learning algorithm are aggregated using the Voting regressor. The aggregating criteria depend on the strategy followed by the voting regressor. The strategy either can be Hard voting or soft voting. In the hard voting, the prediction of each model will be considered and maximum number of models predicting the same results will be considered as the final output. On the other hand, in soft voting, weighted distribution is provided to all the predicted outcomes of models. Voting regressor is considered as one of the very efficient approaches to boost the performance as compared to the base estimator performance. In this research, Linear Regression, Random Forest and K-nearest neighbour models' estimation are ensembled using the voting regressor approach and optimal prediction is generated. Figure 3, represents the working mechanism of Voting Regressor algorithm.

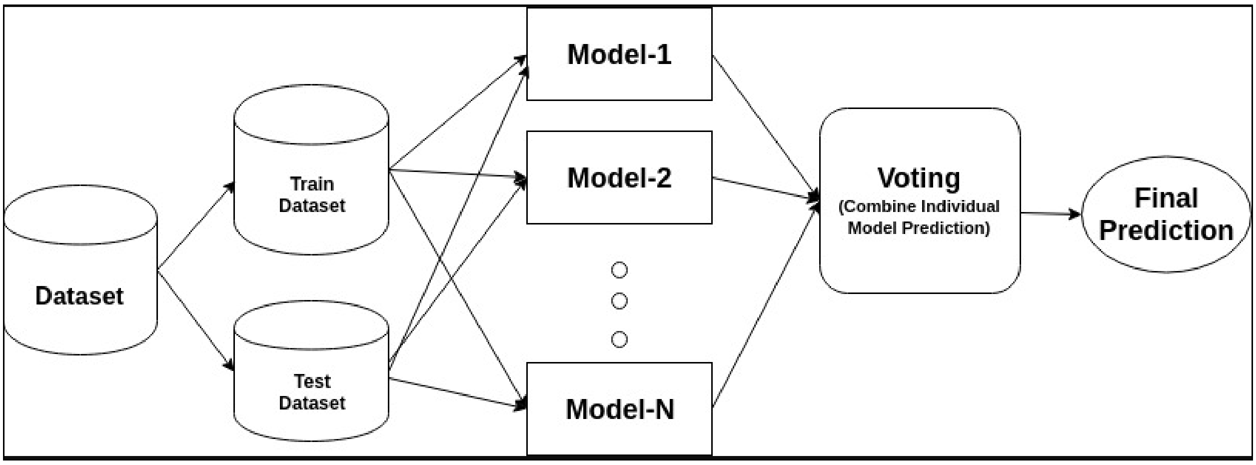

Figure 3 Voting Regressor Algorithm Working Mechanism

5 Implementation

There are several tools and technologies have been used in order to develop the Cloud computing framework. The overall architecture has been developed using the python language. Where establishing the connection between the component IPC (Interprocess communication) has been utilized. Inter-process communication is very similar to sockets used in TCP/IP Networking. Our developed system runs for a fixed number of cycles; these number of cycles can be configured in our application. The data generation has been performed by considering the two different cycles, the user cycle and the energy cycle both the cycles are periodic in nature with some randomness associated with them. Therefore, for generating the dataset sin wave function has been used, where the load and energy generation increase and decrease with respect to time. Green energy generation by the renewable source of energy in each cluster is displayed with help of graph in Figure 4.

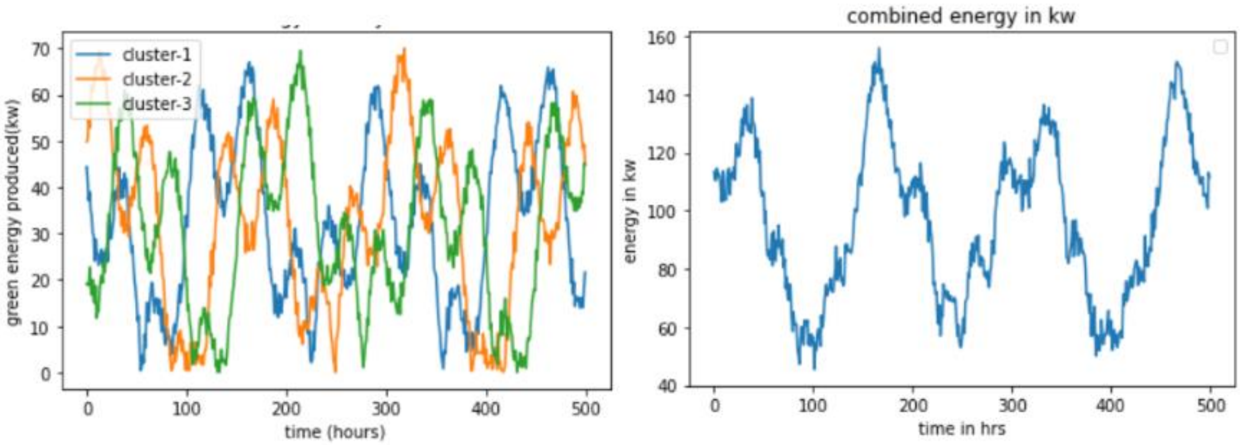

Figure 4 Energy Generation Based On each Cycle

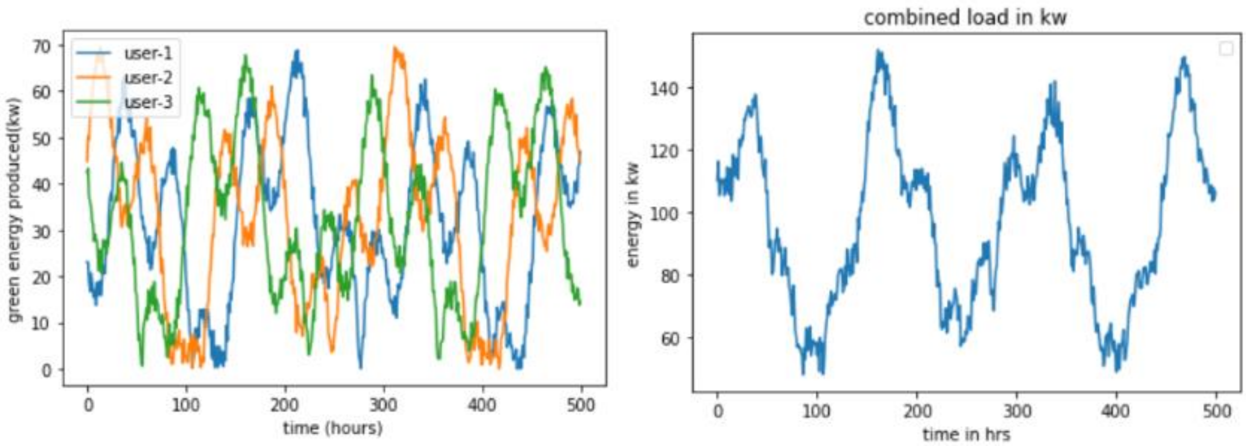

Figure 5 User Load Generation based on Each Cycle

On the other side, the load generated with respect to each user and overall load generated for the 500 cycles is shown in Figure 5. There are several sets of python libraries have been used such as NumPy, multiprocessing library has been used for numerical calculations. Libraries such as Matplotlib have been used for visualization of the outcomes with graph and scikit-learn library have been used to train the machine learning models and make the predictions. Pickle library has been used to save the model for making future predictions. The entire application has been hosted to Amazon EC2 Instance. The Amazon Ec2 with following configuration has been used to run the project.

Cloud Instance Configuration	
Cloud Instance	Amazon EC2
Operating System	Ubuntu-22 (Linux)
Disk (SSD)	50GB
RAM	8GB
Python Library	Numpy, Matplotlib, Scikit-learn, and Pickle

6 Evaluation

As described in Chapter 3, for provisioner multiple sets of algorithms will be applied and best algorithm, forecasting the correct energy estimations will be deployed in the cloud computing architecture. However, analysing the performance of each algorithm is a challenging task and for analysing the performance of algorithms, each algorithm needs to be deployed in our cloud architecture and then needs to be tested with certain set of metrics. There are two main metrics based on which the performance of our cloud computing can be calculated.

6.1 Evaluation Based on Prediction Accuracy

As we are using the online machine learning algorithm over each period of time the prediction is done. We are running the overall system for 500 cycles. Based on each cycle the generated energy varies with time. In the first experiment, we have forecasted the energy over each time stamp. If the difference between actual energy and predicted energy is higher, this indicates that model is not performing well. The first implemented algorithm over the cloud architecture is linear regression. The actual energy vs predicted energy graph is shown in Figure 6.

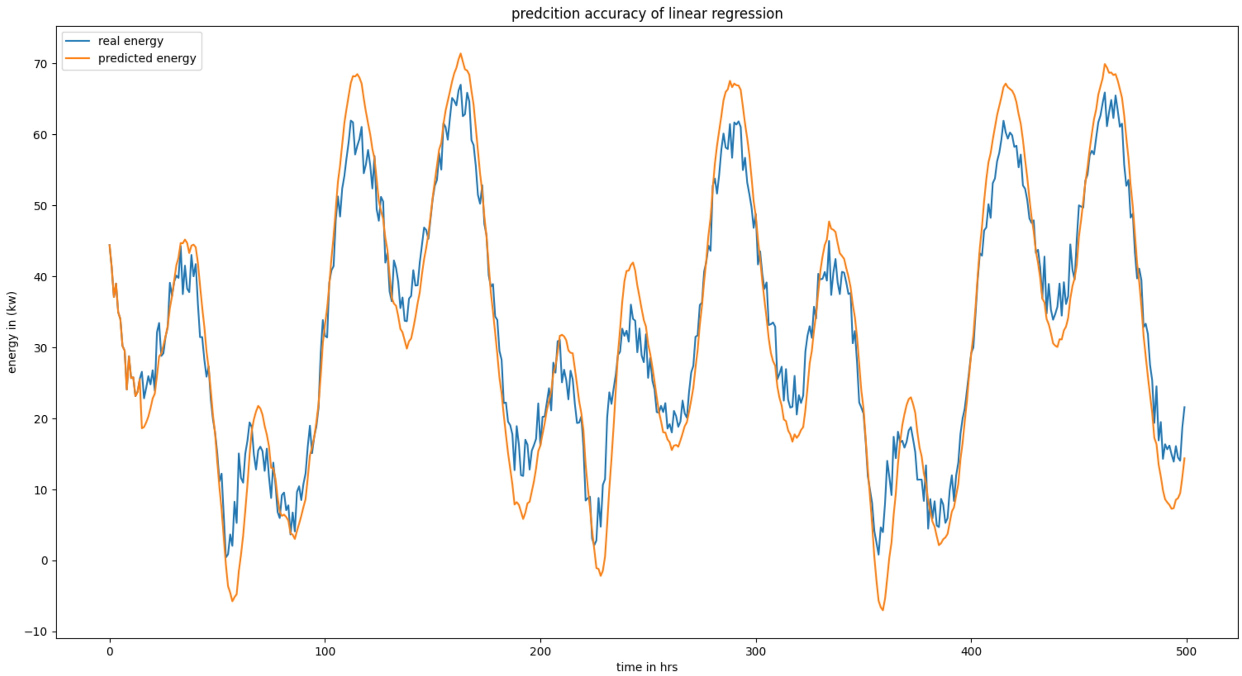

Figure 6. Average vs Predicted Energy using Linear Regression

On analysing Figure 6, it has been observed that linear regression performs quite well in terms of forecasting energy. In most cases, predictions are only wrong when there is a sudden spike in energy or sudden downfall in the energy. Linear regression overprovisions the energy when the energy generation is higher and under-provisioning of energy when energy generation reduces. In case of overprovisioning of energy, more amount of load will be allocated to cluster, where actual energy generated will be less in such cases efficient utilization of renewable energy won't be possible and computational overhead on the server can be observed. The problem of overprovisioning of energy has been identified with the linear regression algorithm. Similar experimentation of predicted energy and actual energy is performed with the support vector regression algorithm, the obtained using SVR are shown in Figure 7.

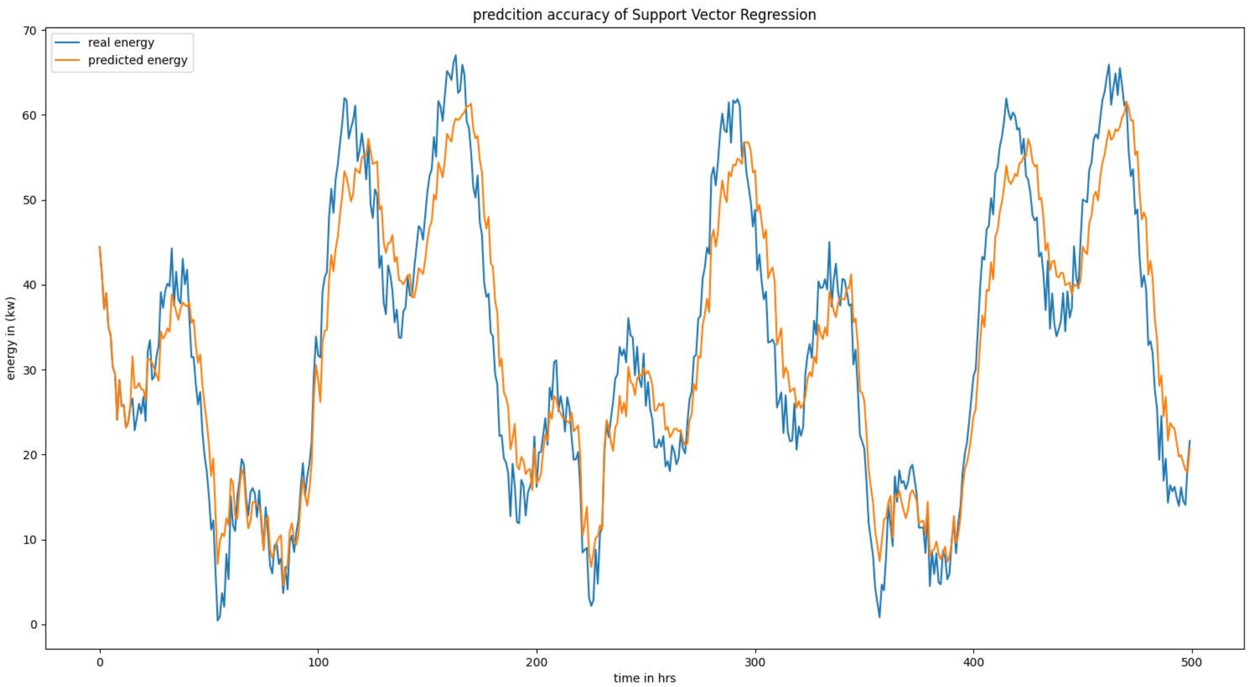

Figure 7. Actual Vs Predicted Energy Using Support Vector Regressor

After analysing the outcomes of support vector regressor it has been found that, predicted energy was always found to be less than actual generated energy. In such cases, the broker does not allocate a sufficient amount of load to the cluster based on its capacity. In such cases, most of the resources are underutilized, virtual machines spend their most of time doing nothing. Another similar experimentation has been performed with the Bayesian regression algorithm. The Predicted vs actual energy of Bayesian model has been shown in Figure 8.

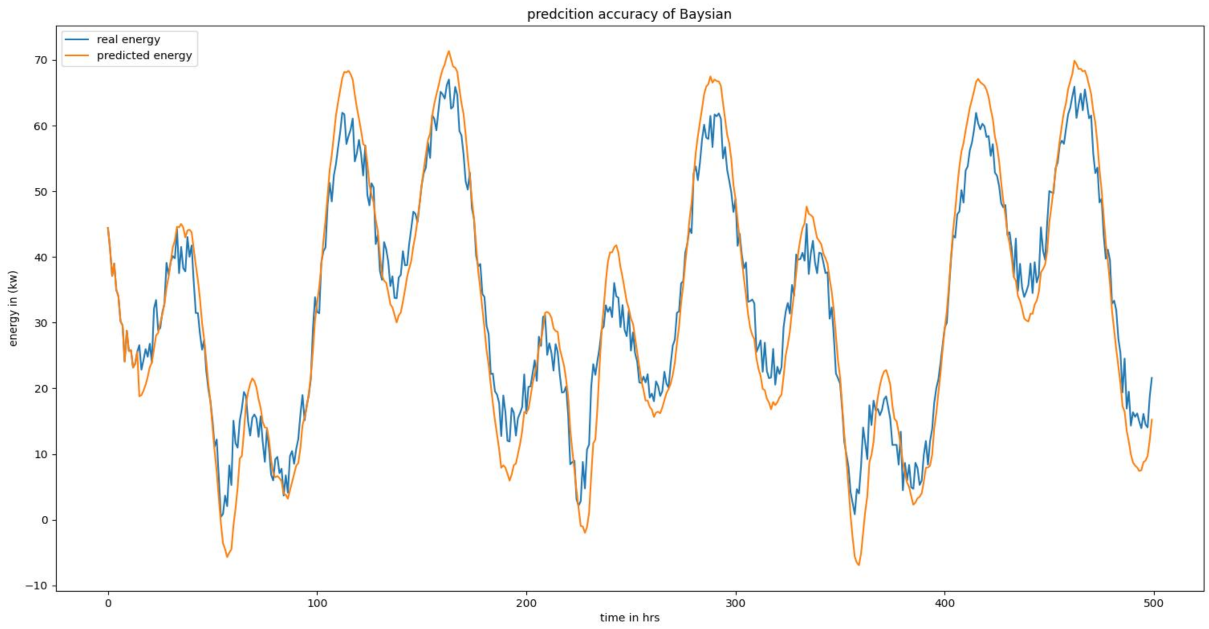

Figure 8. Actual Vs Predicted Energy Using Bayesian Regressor

On observing the Prediction graph of Bayesian regressor, it has been analyzed that forecasting done by Bayesian regressor is quite accurate than the support vector regressor. However, On the sudden spike of energy, the predicted energy is found to be more than the actual energy. Based on which computation overhead on the server can increase. The results of linear regressor and Bayesian regressor are found to be quite similar, with this observation it is very difficult to say which algorithm performs better. Another observation has been performed over the Ensemble Regressor, where the graph for predicted energy vs actual energy is shown in Figure 9.

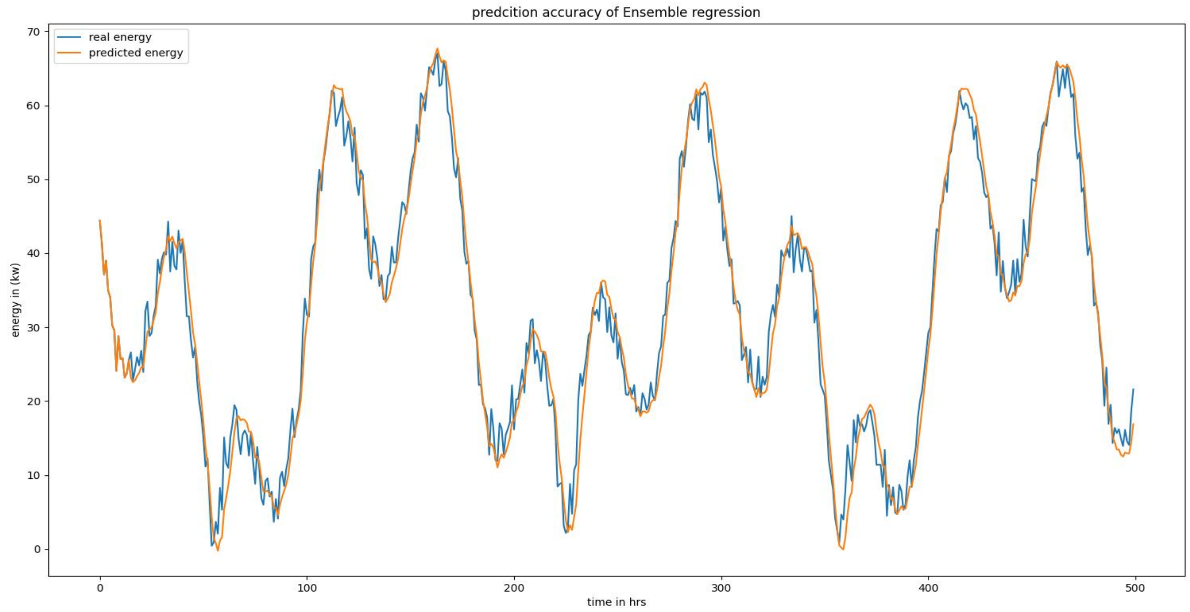

Figure 9 Actual Vs Predicted Energy using Ensemble Regressor

On Analyzing the graph of Ensemble regressor as shown in Figure 9. It has been observed that over every period of cycle the difference between the predicted energy and actual energy is very minimal. On performing comparative analysis with other algorithms, the results of Ensemble regression algorithm are found to much better, which can help to make accurate provisioning of resources and load.

6.2 Evaluation Based on Energy Wasted (Cluster Wise)

By utilizing the green computing criteria and renewable sources of energy, the accurate utilization of energy is not possible. However, energy wastage can be reduced by choosing an optimal strategic algorithm. As per our architecture cloud system consists of 3 different clusters available in different regions of the world. The broker allocates the load as per the energy prediction done by the provisioner algorithm. Therefore, after running the application over several number of cycles, the energy wastages based on each algorithm can be calculated based on each cluster. The algorithm calculating the minimum energy wastage will be considered the most optimal algorithm for cloud environment. Cluster-wise energy wastage for linear regression algorithm is shown in Figure 10.

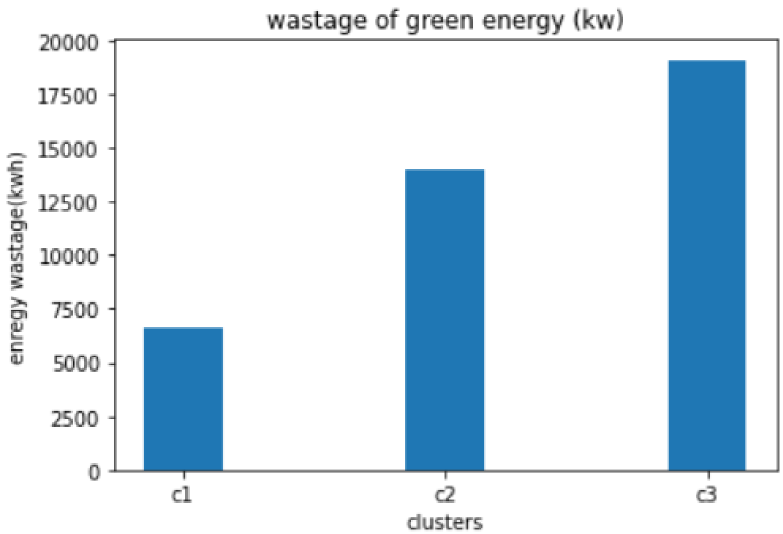

Figure 10. Wastage of Energy Based on Linear Regression (Cluster-wise)

After analyzing the graph shown in Figure 10, it has been noted that after running the cloud system with linear regression algorithm over the 500 number of cycles, the wastage of green energy made by cluster-1 is 6613 Kilowatt. Other the hand cluster-2 green energy wastage is higher with the energy values of 14005 kilowatt. Cluster-3 wastage of green energy is 19099. Similarly, calculating now has been performed for support vector regressor model, the green energy wastage graph using support vector regressor is shown in Figure 11.

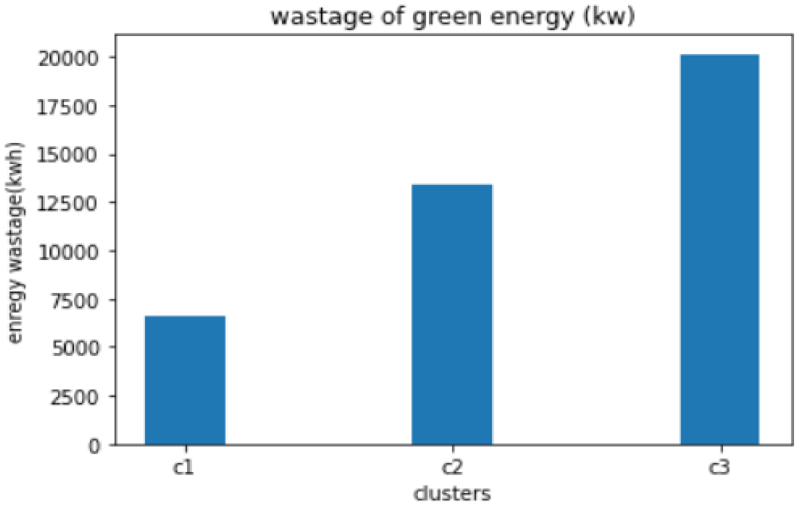

Figure 11 Wastage of Energy Based on SVR (Cluster-wise)

On observing the green energy wasted by each cluster for SVR, the energy wastage obtained by Cluster-1, Cluster-2 and Cluster-3 are 6622 kwh, 13394 kwh, 20141 kwh. On comparing these values with linear regression method, the green energy wastage is found to be higher as compared to the linear regression approach. Thus, it can be clearly said that SVR is not able to correctly forecast the energy. In the next experiment, the green energy wastage for Bayesian regression algorithm is calculated as shown in Figure 12.

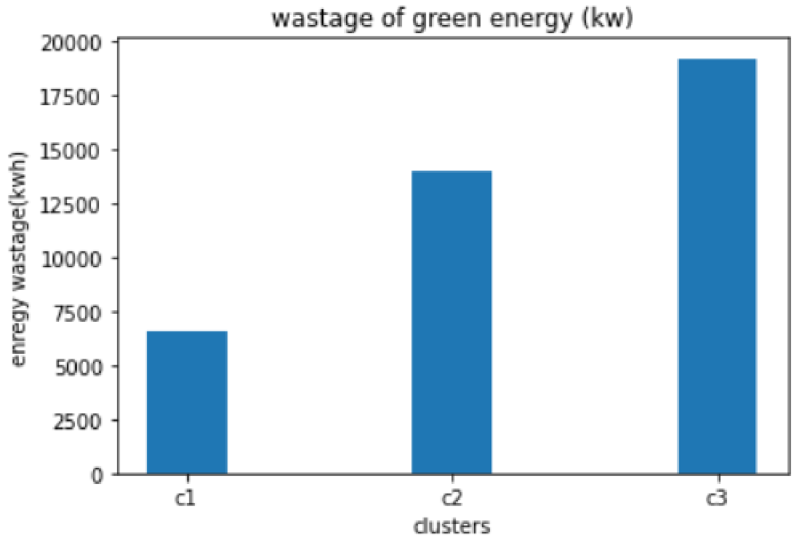

Figure 12. Wastage of Energy Based on Bayesian Regression (Cluster-wise)

Wastage of green energy by cluster-1, cluster-2, and cluster-3 generated by Bayesian regression is 6537 kwh, 14009 kwh, and 19199 kwh. On comparing these results with support vector machine and linear regression method, wastage energy for some clusters is higher and some clusters are lower. Although it is very difficult to compare the linear regression algorithm and Bayesian algorithm. For further analysis, the green energy wastage has been calculated for Ensemble regressor model as shown in Figure 13.

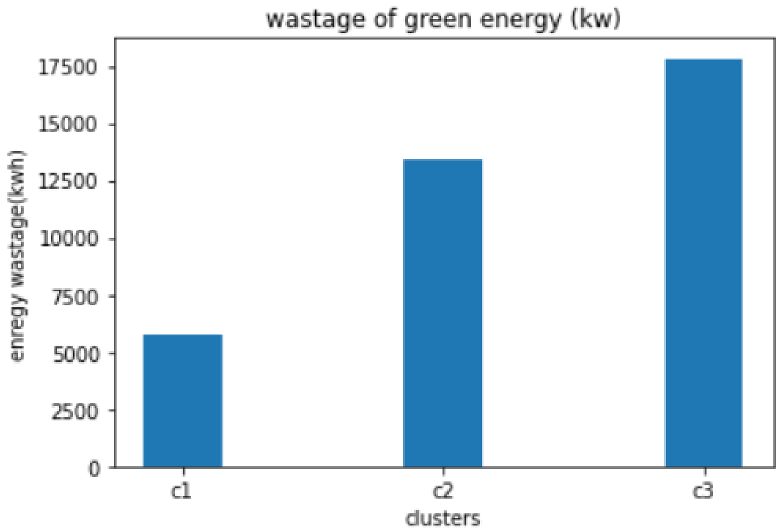

Figure 13. Wastage of Energy Based on Ensemble Regressor (Cluster-wise)

The obtained green energy wastage with Ensemble regressor model for Cluster-1, Cluster-2, and Cluster-3 are 5710 kwh, 13370 kwh, and 17825 kwh. The obtained green energy wastage of all the clusters using Ensemble regressor is found to very minimal as compared to the rest of models including SVR, linear regression, and Bayesian regression. Thus, it can be clearly said that in terms of minimizing the green energy wastage, the Ensemble regressor outputs are found to be quite impressive.

6.3 Evaluation Based on Total Energy Wasted

For better analysis, all the green energy wastage generated by all the clusters for each algorithm is combined. Total green energy wastage based on each algorithm will give us better insight into the algorithm's performance. For a comparative analysis, the total green energy wastage by each algorithm is shown in Figure 14. For linear regression, the total green energy wastage is 39718 kwh, for support vector regressor the green energy wastage is 40159 kwh, for Bayesian regressor the wastage of energy is found to be 39745 kwh, and ensemble regressor green energy wastage is noted as 36906 kwh. The graph clearly indicates that Ensemble regressor is the most efficient and optimal model for reducing green energy wastage and is also able to correctly forecast the energy based on which proportionally load can be distributed and efficient migration can be performed.

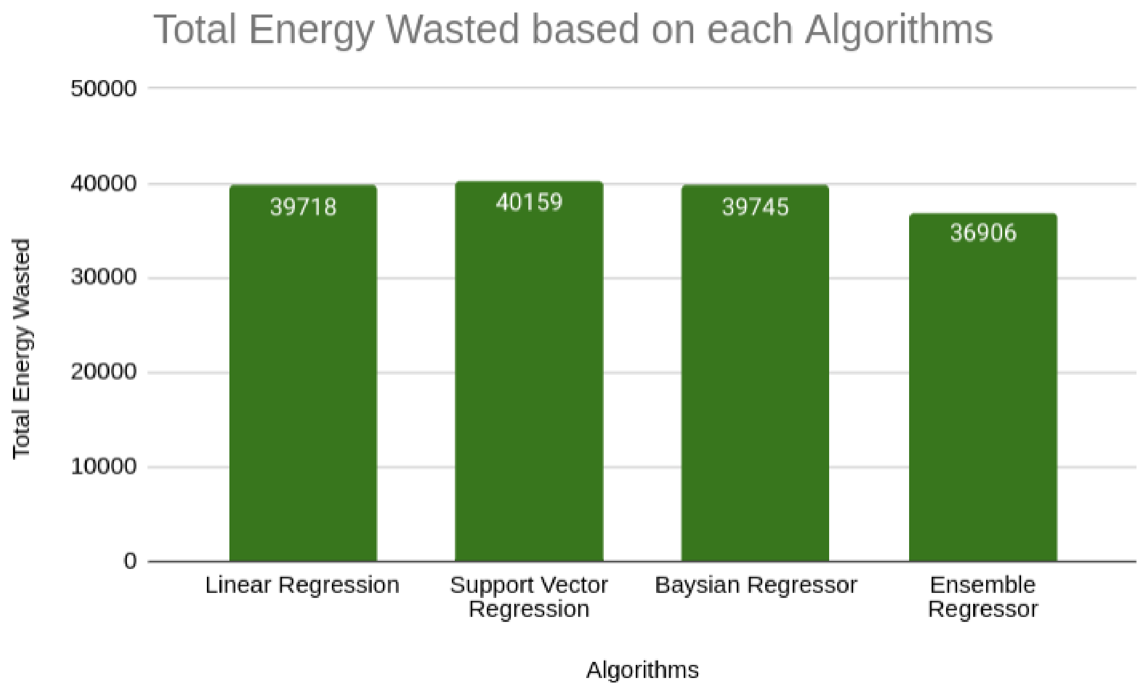

Figure 14 Total Energy Wasted Based on each Algorithm

6.4 Discussion

In the research, three different metrics have been calculated in order to identify the best algorithm for provisioners to efficiently manage the cloud computing system. After a certain set of experiments and analysis, it has been found that Ensemble Regressor is the most efficient model, which not only correctly forecasts the energy also helps to reduce green energy wastage. Along with it, it helps the broker and migrator to allocate the proportional load and migrate the VMs as per the energy availability of cluster. Other than the ensemble learning approach the second-best algorithm can be considered linear regression, which has given quite accurate outcomes. Similar or very close results to linear regression have been calculated by Bayesian regressor method, therefore based on accuracy, it was very difficult to identify the performance difference between these two models, and at last, the support vector regressor is considered as poorest model for making the energy forecasting and thus should not be used for provisioner in cloud computing architecture.

7 Conclusion and Future Work

Due to the advancement in technology, green computing solutions are being adopted by most organizations as it is an environment-friendly, cost-efficient, and scalable solutions. The main objective of this research is maximum utilization of green energy by the data centers. But due to certain factors and dependency on the environment/weather conditions, the power generation is very dynamic, and sometimes, it is unpredictable. Therefore, in order to solve such challenges in this work AI-based Ensembled regressor algorithm is proposed, which can make accurate predictions of energy in real-time based on historical data. Our methodology architecture used in this research simulates the real-world cloud environment where the functionality of each component is similar to actual cloud component. After conducting a certain set of experiments and running the application over 500 number of cycles, we have obtained the Minimum wastage of green energy using Ensemble regressor followed by linear regressor and Bayesian regressor. On analyzing the graph of ensemble regressor for actual vs predicted energy also it has been identified that over every cycle the ensemble regressor model has forecasted a very close and accurate value to the actual energy generation. This accurate prediction prevents the system from under-provisioning and over-provisioning of resources and load in cloud computing environment. With the help of accurate prediction of ensemble regressor Virtual machine migrations can be reduced to a great extent and if required, can be performed at an advanced stage without disrupting the existing services. The concept of ensemble regressor algorithm can be incorporated into the real cloud computing environment, where the actual data can be captured from energy generation units of renewable sources and predictions can be made, and later, performance can be analyzed. In future work, this research can be performed over a large set of energy data, which can be collected from the various sensors available in data center of the cloud. To make the predictions over the large volume of data, deep learning-based algorithms can be used which can provide more accurate solutions and can make the predictions in real-time.

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