ROBUST ENERGY AWARE TASK SCHEDULING FOR SCIENTIFIC WORKFLOW IN CLOUD COMPUTING

Dissertation submitted in fulfilment of the requirements for the Degree of

MASTER OF TECHNOLOGY

in

COMPUTER SCIENCE AND ENGINEERING

By

PRIYA KUMARI

11507058

Supervisor

Ms. Avinash Kaur

School of Computer Science and Engineering

Lovely Professional University

Phagwara, Punjab (India)

May, 2017

PAC FORM

TOPIC APPROVAL PERFORMA

School of Computer Science and Engineering

Program : P172::M.Tech. (Computer Science and Engineering) [Full Time]

COURSE CODE : CSE546 **REGULAR/BACKLOG :** Regular **GROUP NUMBER :** CSERGD0017

Supervisor Name : Avinash Kaur **UID :** 14557 **Designation :** Assistant Professor

Qualification : ________________________ **Research Experience :** ________________________

SR.NO.	NAME OF STUDENT	REGISTRATION NO	BATCH	SECTION	CONTACT NUMBER
1	Priya Kumari	11507058	2015	K1518	8437164219

SPECIALIZATION AREA : Database Systems **Supervisor Signature:** ___________________

PROPOSED TOPIC : Robust energy aware task scheduling for scientific workflow in cloud computing

Qualitative Assessment of Proposed Topic by PAC		
Sr.No.	**Parameter**	**Rating (out of 10)**
1	Project Novelty: Potential of the project to create new knowledge	7.25
2	Project Feasibility: Project can be timely carried out in-house with low-cost and available resources in the University by the students.	7.00
3	Project Academic Inputs: Project topic is relevant and makes extensive use of academic inputs in UG program and serves as a culminating effort for core study area of the degree program.	7.50
4	Project Supervision: Project supervisor's is technically competent to guide students, resolve any issues, and impart necessary skills.	7.50
5	Social Applicability: Project work intends to solve a practical problem.	7.00
6	Future Scope: Project has potential to become basis of future research work, publication or patent.	7.50

PAC Committee Members		
PAC Member 1 Name: Janpreet Singh	UID: 11266	Recommended (Y/N): Yes
PAC Member 2 Name: Harjeet Kaur	UID: 12427	Recommended (Y/N): Yes
PAC Member 3 Name: Sawal Tandon	UID: 14770	Recommended (Y/N): Yes
PAC Member 4 Name: Raj Karan Singh	UID: 14307	Recommended (Y/N): NA
DAA Nominee Name: Kanwar Preet Singh	UID: 15367	Recommended (Y/N): Yes

Final Topic Approved by PAC: **Robust energy aware task scheduling for scientific workflow in cloud computing**

Overall Remarks: Approved

PAC CHAIRPERSON Name: 11011::Dr. Rajeev Sobti **Approval Date:** 26 Oct 2016

4/27/2017 4:24:11 PM

ABSTRACT

Cloud computing is an advance computing model using which several applications, data and countless IT services are provided over the Internet. Task scheduling plays a crucial role in cloud computing systems. The issue of task scheduling can be viewed as the finding or searching an optimal mapping/assignment of set of subtasks of different tasks over the available set of resources so that we can achieve the desired goals for tasks. With the enlargement of users of cloud the tasks need to be scheduled. Cloud's performance depends on the task scheduling algorithms used. Numerous algorithms have been submitted in the past to solve the task-scheduling problem for heterogeneous network of computers. The existing research work proposes different methods for data intensive applications which are energy and deadline aware task scheduling method. Existing algorithm is doing offline scheduling of jobs which compromise the SLA while saving the energy. In the proposed research methodology, researcher has extended this technique using dynamic voltage fluctuation system (DVFS). By using DVFS, if further migration is not possible or the number of task running on the machine is going to complete, then migration further reduce the performance. In DVFS, the voltage given to under loaded machines has been reduced which further optimize the energy consumption to next level. Dynamic Voltage and Frequency Scaling (DVFS) can dynamically adjust the frequency and voltage of host's CPU on the basis of load. In the research, DVFS has improved the energy consumption without violating the SLA but in existing technique, the energy consumption is more as well as it compromises the SLA.

DECLARATION STATEMENT

I hereby declare that the research work reported in the dissertation entitled "ROBUST ENERGY AWARE TASK SCHEDULING FOR SCIENTIFIC WORKFLOW IN CLOUD COMPUTING" in partial fulfilment of the requirement for the award of Degree for Master of Technology in Computer Science and Engineering at Lovely Professional University, Phagwara, India is an authentic work carried out under supervision of my research supervisor Ms. Avinash Kaur. I have not submitted this work elsewhere for any degree or diploma.

I understand that the work presented herewith is in direct compliance with Lovely Professional University's Policy on plagiarism, intellectual property rights, and highest standards of moral and ethical conduct. Therefore, to the best of my knowledge, the content of this dissertation represents authentic and honest research effort conducted, in its entirety, by me. I am fully responsible for the contents of my dissertation work.

Signature of Candidate

Priya Kumari

11507058

SUPERVISOR'S CERTIFICATE

This is to certify that the work reported in the M.Tech Dissertation entitled "**ROBUST ENERGY AWARE TASK SCHEDULING FOR SCIENTIFIC WORKFLOW IN CLOUD COMPUTING"**, submitted by **Priya Kumari** at **Lovely Professional University, Phagwara, India** is a bonafide record of her original work carried out under my supervision. This work has not been submitted elsewhere for any other degree.

Signature of Supervisor

Ms. Avinash Kaur

Date:

Counter Signed by:

1) **Concerned HOD:**

   HoD's Signature: ________________

   HoD Name: ____________________

   Date: ___________________

2) **Neutral Examiners:**

   External Examiner

   Signature: ________________

   Name: ___________________

   Affiliation: _______________

   Date: ____________________

   Internal Examiner

   Signature: ________________

   Name: ___________________

   Date: ____________________

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my advisor Ms. Avinash Kaur for the continuous support for this study, for her patience, motivation, enthusiasm and immense knowledge. Her guidance helped me all the time of research and writing this dissertation1 report. I could not have imagined having a better advisor and mentor for my M.Tech study.

Her meticulous approach has improved the precision and clarity of my writing. I sincerely thank my family for unconditional support, trust and infinite love because of their encouragement; I would have been able to complete my work with zeal.

This research work is made possible through the help and support from everyone, including my parents, teachers, family, friends, and in essence, all sentient beings. Especially, please allow me to dedicate my acknowledgment of gratitude toward the following significant advisors and contributors.

TABLE OF CONTENTS

CONTENTS **PAGE NO.**

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO CLOUD COMPUTING

The usage of internet and new technologies is part of today's world. Any kind of information is available throughout the world at any instance of time. All these kinds of things were not available few years back. Lot of possibilities has arisen for accessing the public and private information like speedy access of internet [1]. To make a connection to internet by sitting anywhere in the world have led to lot of development.

Nowadays collaborative documents are being written through web browsers, online mails are consulted through webmail clients, virtual albums are created for uploading the photographs of holidays. The applications are executed and data is stored in servers that are located not on their own computer but on internet somewhere. The only thing that the user needs to learn to begin to use the internet services is enter in the web page. By this the user is able to make usage of services that share the confidential and private information which reside on the remote server [2]. These kinds of services are termed as cloud computing services. That name is given because of the metaphor about Internet.

These services that can be made available in any mode either pay on demand or free. It can be simply like calling a function (like asking the weather in some country in the world to be included in web page or usage of virtual machine with its own applications, operating system and space of storage for running applications). This refers to that many organizations and users can install only the required application on their computer and can attain more computational capacity by accessing the services of the cloud through internet [3]. Own private cloud can also be made to manage itself completely or one can consider both the options together too.

In the 60's John McCarthy said that "computation may someday be organized as a public utility". This is just as cloud computing. Like power suppliers serves the user has to just pay the usage charges, with an illusion of infinite supply. In the years of 60 and 70 the services were provided to workers that had the access rights of large mainframe computers through the dumb terminals. All the calculation and storage of information was provided by these. The terminal sent the commands to mainframe computers which in turn returned the necessary information to terminal. But these large mainframes were very costly.

In the year of 80, it was found that lower cost installation of servers can be performed based on the computers thus overcoming the disadvantage of mainframes. Hence the larger control was shifted into the hands of the user by replacement of mainframes with the personal computers. The prices also dropped for personal computers.

In the year of 90, the trend of many computers accessing one large server came back with the global usage of internet. The requirement of that era was larger capacity web servers for handling large number of requests from internet. Large number of services is offered by internet and more amount of storage capacity is required by the users. There is continuous process of sending and receiving of applications that depends on the speed of internet [4]. Thus the efficiency can be maximized by sharing the same infrastructure and minimizing the costs. Salesforce.com in 1999 started delivering services to enterprise through their own website and introduced the concept of software as a service. The Amazon web services was launched by Amazon in 2002 [1], that included computation, storage and other services. Elastic Compute Cloud (EC2) [3] was launched by Amazon to small companies that allowed the users for executing their own applications in cloud. Eucalyptus was launched in 2008, which was the first open source AWS API [5] compatible platform for deployment in private clouds. Enterprise application as Google Apps based in browser was offered by Google in 2009 [4].

1.2 CHARACTERISTICS OF CLOUD

The essential characteristics of cloud are:-

- **On demand service**

  The services provide in cloud computing should elasticity feature. The resources can be assigned and taken back as per the requirement of the user and applications [1]. The human interaction should not be involved and management should do automatically by the system.

- **Measured Services**

  Metering capability of the cloud provide the facility to automatically use and optimize the resources. The monitoring of resources done automatically and parallel controlled the environment [1].

- **Rapid Elasticity**

  The scale up/down and in/out of resources is rapidly done by the cloud computing system. The user can acquire the resources as per the demand. The scale down automatically is done when the resource is no longer required by the user application [2].

- **Broad Network Access**

  User can access the resources through certain mechanism. The heterogeneous resources are the combination of thick or thin clients [3].

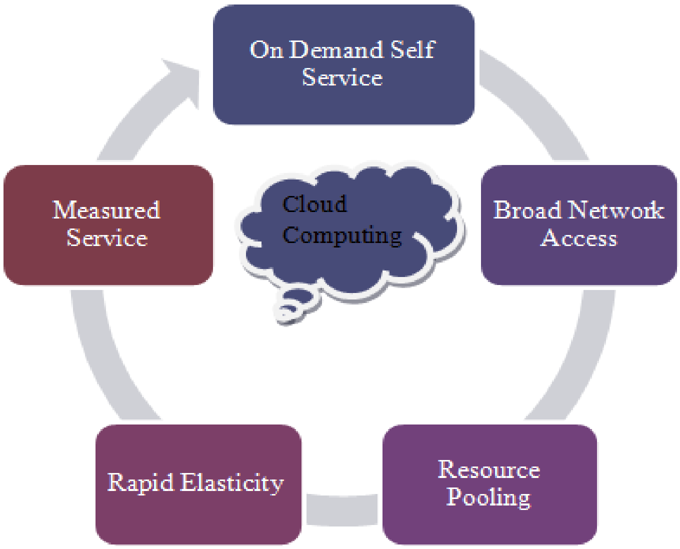


Figure 1.1: Essential characteristics of cloud [7].

- **Resource Pooling**

  Using multi-tenant environment the resources can be used by the multiple consumers. The users have not the control on the location of the resources [6]. Through multi-tenant system, services are provided to multiple tenant with sharing of resources. The virtual and physical resources are assigned through pay per use basis. Isolation between the task of multi-tenant will be provided.

1.3 TYPES OF CLOUD

The Cloud is broadly classified into four categories as per the sharing of resources among the users.

- **Public**

  The traditional way of providing services by the third party through internet is public cloud. It is also known as the external cloud. These services are available for everyone. But these services are not freely available. Large amount of information of different users are available on cloud, but no one has the right to access the information of any other user.

- **Private**

  The hosting of large amount of private applications, private capacity to the individual users is provided by the private cloud. The space for computation capacity is also provided by the cloud and this cloud gives the space for private use. The infrastructure and maintenance cost is same as public cloud only but the scalability and sharing cost is higher in this.

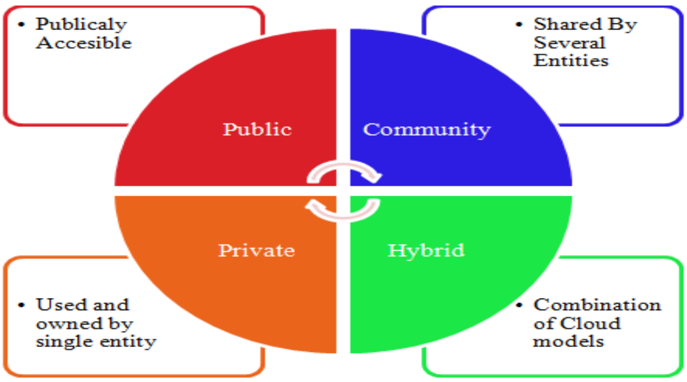


Figure 1 2: Types of cloud [1].

- **Community**

  The community cloud is used by the group of same objective sharing organizations. The data centre can be managed on any location among the organization. The management of resource can be done by third party also.

- **Hybrid**

  It is the combination of private cloud and public cloud. The part of services of an organization can be in their own infrastructure and it can also be in public cloud. The usage of public services can be made in the peak usage time. It is the best option when the data and application is available for user in local and cost to be involved in infrastructure is low [6].

1.4 SCIENTIFIC WORKFLOW

A scientific workflow is specification of process to streamline automates and represents the schedule of integration, dataset selection, analysis and computation for the final presentation and visualization [9]. Scientific disciplines are knowledge driven with the help of data analysis and discovery pipeline. The series of data intensive and computational intensive tasks are designed composed and executed. The grid and cloud computing infrastructure attracts the scientist community the features such as sharing of computation, storage and software licenses. Multidisciplinary fields such as Bio-informatics, cheminformatics, geoinformatics etc. doing large investment on IT infrastructure. The communities of scientists are interested in robust middleware which could afford the requirements of scientific tasks.

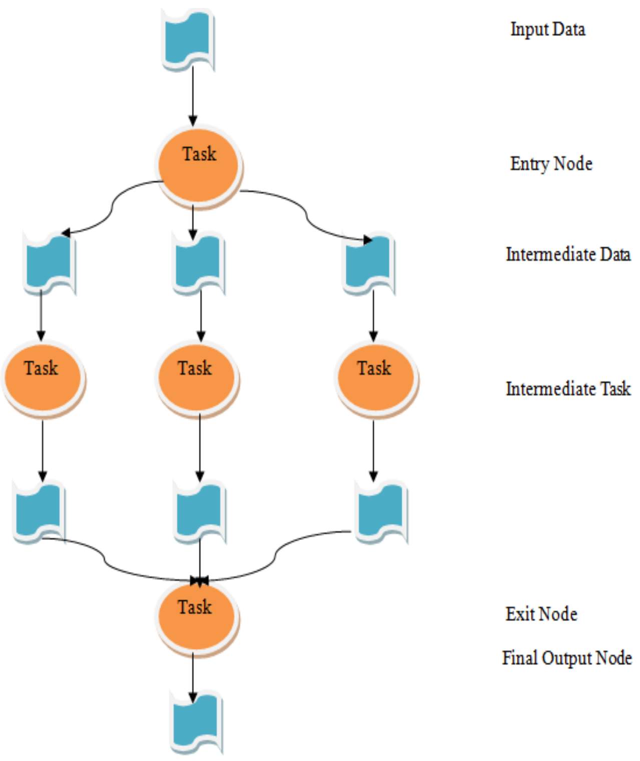


Figure 1.3: Scientific workflow [19].

1.4.1 EXAMPLES OF SCIENTIC WORKFLOW

- **EPIGENOMICS**

  It is an information parallel work process. The Illumina-Solexa Genetic Analyzer gave us a Beginning information which is in the form of DNA grouping paths. Different paths of DNA successions can be produced by every Solexa machine. These information are changed over into a configuration that can be utilized by the software which is sequence mapping. One of two noteworthy undertakings can be done by the mapping software. It either takes all the short peruses, regards them as little pieces in an astound and afterward tries to amass a whole genome, or maps short DNA peruses from the arrangement information onto a reference genome. DNA arrangements then mapped to the right areas in a reference Geome by workflow. This produces a guide that shows the grouping thickness demonstrating how often a specific arrangement communicates on a specific area on the reference genome [6].

- **MONTAGE**

  The montage scientific workflow is used to compute the mosaics of the sky images. The images collected first re-projected as per the coordinates. Next rectification of background has taken place. The co-added has done to create a big picture of sky. The project has been funded by NASA [6].

- **CYBERSHAKE**

  In the Southern California area a seismology application named CyberShake used to figures Probabilistic Seismic Hazard that are bends for geographic locations. This distinguishes all cracks inside 200km of the site of concern. It changes over burst definition into different varieties with contrasting hypocenter areas and slip circulations. Next step is to figures peak intensity measures and seismograms for each burst difference and joined with the first break probabilities to deliver probabilistic seismic risk bends for the site [7].

- **LIGO**

  Laser Interferometer Gravitational-Wave Observatory is observing and analysis astrophysical gravitational waves and further incorporates the data in the astronomy and physics research. The LIGO deals with black holes, gravity and nuclear matters [7]. It is observing the birth of new black holes, stars and supernova in the universe.

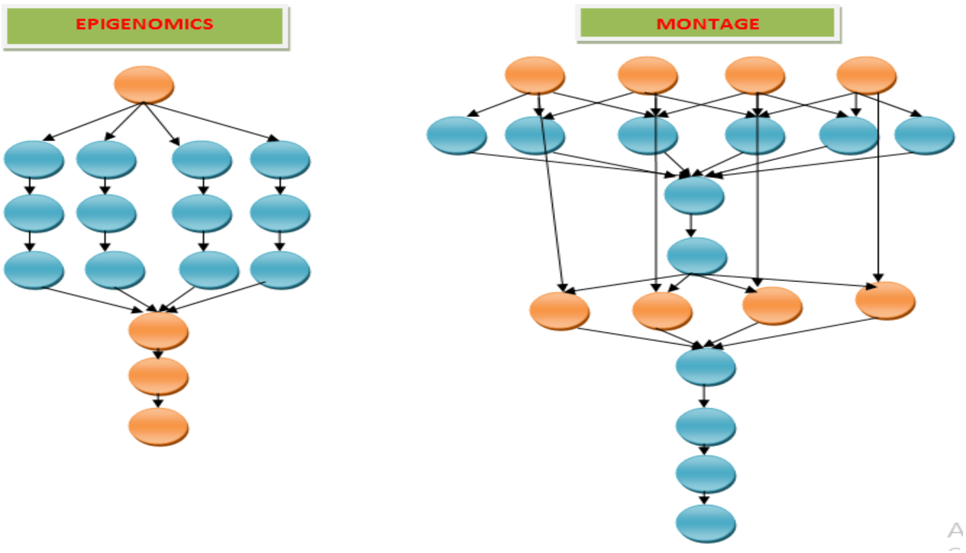


Figure 1.4: Scientific workflow examples [4].

1.4.2 WORKFLOW STRUCTURE

A workflow is combination of various tasks according to the dependencies. It indicates the temporary relationship between the tasks. The sequence and parallelism performs the task concurrently.

1.4.3 WORKFLOW MODEL

Workflow model is also known as workflow specification. Types of models are: abstract and concrete. Abstract resources are not bind to any specific resources while concrete tasks are bind with the resources.

1.4.4 WORKFLOW COMPOSITION MODEL

It enables the user to design their workflow. The graphical oriented designing can be done in the workflow composition system.

1.5 SCIENTIFIC WORKFLOW MANAGEMENT SYSTEM

To perform execution of computational tasks in cloud environment the scientific workflow management system. The scientist community has vision to perform high computation task on the distributed system with large computations and data intensive applications. Front end can be enabling by many server side languages to input the task to the environment. Figure 1.5 describes the workflow management system.

- **OPERATION LAYER**

  This layer consists of the cloud services and resources. It provide the wide range of homogeneous and heterogeneous resources, tools and services to manage the scientific workflow.

- **TASK MANAGEMENT LAYER**

  Task management layer handles the data product. The data product consists of heterogeneous data. Isolation of operation layer and task management layer defined in the reference model. The abstraction is provided by the task management layer.

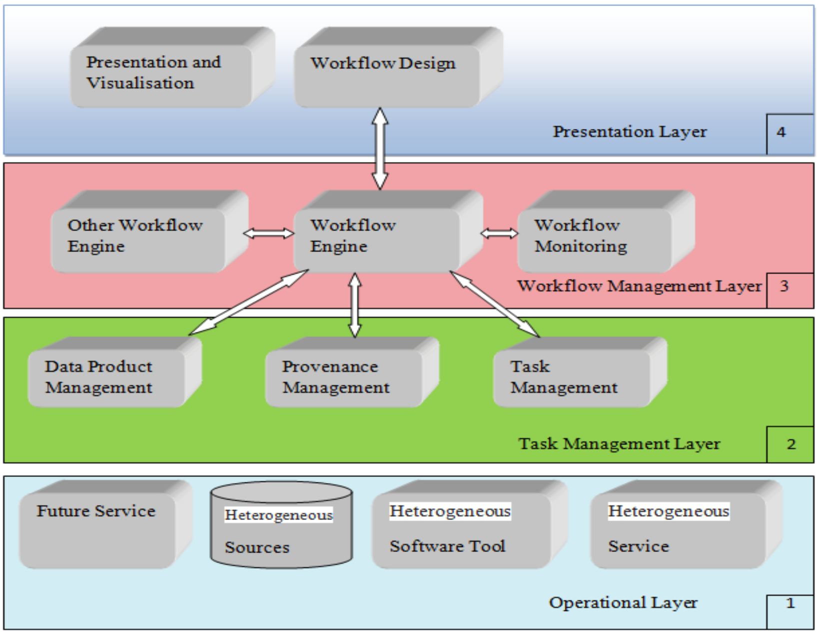


Figure 1.5: Cloud workflow management system [2].

- **WORKFLOW MANAGEMENT LAYER**

  This layer is responsible for the monitoring and execution of the scientific workflow. This is an important layer of scientific workflow management system. The workflow management layer provides the isolation of the workflow logic from the task execution.

- **PRESENTATION LAYER**

  The workflow design is the responsibility of the presentation layer. It is providing interface to the lower layers. Isolation between the these layer provide the facility to change or update each component towards the updating in the technology [8].

To characterize and display the unique work processes like assignments and their conditions a workflow portal is utilized. A dialect parser is used to parse in workflow enactment engine and takes the theoretical workflow. Non critical failure will be handled by workflow enactment engine.

At that point, the assignment dispatcher investigations the conditions then dispatches the prepared undertakings to the scheduler. The scheduler, in light of the characterized planning calculations plans the work process undertaking onto an asset. It additionally contains an asset portion segment which designates assets to the errands through the asset agent. An Asset agent gives a brought together view to the enactment engine it directly interface with framework layer [3]. The asset merchant speaks with process administrations to give the coveted asset. The index and inventory administrations house data about the process assets, the application and object of information. Workflow engine utilized this data, and the asset merchant to settle on basic choices.

When all is said in done, workflow management service give critical administrations that are fundamental for the working of a WFMS. A guarantee validation and secure access to the WFMS will be given by workflow services. Observing devices continually screen fundamental parts of the WFMS it then raise alerts at fitting circumstances. A dependable stockpiling to intermediate and last information consequences of the work processes is given by Database administration segment. Provenance administration catches vital data, for example, elements of control streams and information, their movements, execution data, record areas, information and yield data, work process structure, framework data, work process development and frame [9]. Provenance is basic for deciphering information, investigating, and proprietorship, streamlining proficiency, giving again producible outcomes and deciding its quality furthermore to give adaptation to internal failure.

1.6 WORKFLOW SCHEDULING

Workflow scheduling do the mapping and management of workflow task execution on the resources which are on distributed environment and not under the control of the workflow management system.

1.6.1 SCHEDULING ARCHITECTURE

The scheduling Architecture is categories into three categories:

- Centralized
- Hierarchical
- Decentralized

The centralized scheduler works at the central server and designs the scheduling policy for every task. In the hierarchical scheduling, centralized manger is working at top level and also there is sub tree level scheduler also. The scheduler without any central control comes under the decentralized scheduler. The centralized scheduler gives high performance [10].

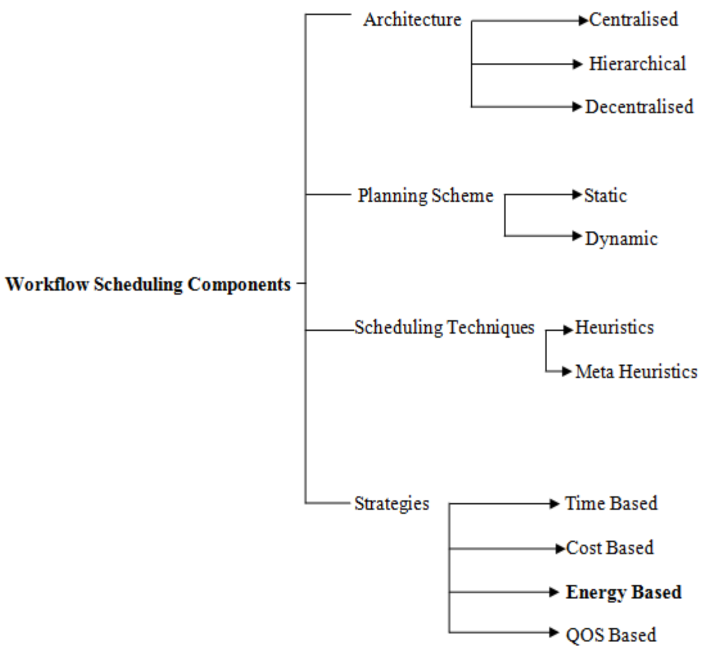


Figure 1.6: Components of workflow scheduling [19].

1.6.2 DECISION MAKING

The scientific workflow scheduling is very complex task. There is no best solution for each and every problem. The decision making process is further categorized into two: Local decisions and Global decision. The decision taken places at the central level is known as global decisions, while the decision taken place at machine or sub tree level is known as local decision.

1.6.3 PLANNING SCHEME

As the user input the abstract module, where there is no information regarding the resources. To convert the abstract task to concrete task with resources information is the main task of planning scheme. It is also divided in two parts: Static and Dynamic. Static scheme can be done by the user by doing the simulation or user directed based. From the simulation process user can get to know about the preferences and performance criteria. Dynamic schemes are work on the forecasting. The task performance prediction is done same as static scheme but all the task are performed just-in-time based model. The scheduling decision change dynamically.

1.6.4 SCHEDULING STRATEGY

The scheduling of task in NP complete problem. Many techniques are developed and find the near optimal solution for the scientific workflow applications. The schedule strategy needs to design again as per the requirement change of the user according the QoS parameters.

1.6.5 CHALLENGES OF SCHEDULING IN CLOUD COMPUTING

- **Resource Scheduling**
  The main threat in resource scheduling involves uncertainty, heterogeneity, dispersion of resources that are not been resolved by existing algorithms. So it is necessary to create efficient cloud services by taken care of those properties.
- **Quality of service(QOS)**
  Required number of resources are provided by service providers to satisfy the QOS necessities of cloud administration. So sufficient number of resources should be provisioned dynamically by service providers that decrease SLA violation.
- **Service Level Agreement**
  The main issue is to find effective strategy that could find SLA violation earlier that can avoid performance degradation. So there is requirement of

autonomous cloud infrastructure to accomplish the QOS specification on the basis of SLA.

- **Energy Management**

  The data centers are consumed huge energy and this ratio is increased as per the establishment of new data datacenters. So infrastructure providers are in great pressure to minimize energy. Their motive is to not to minimize the energy cost but also meet the environment standards.

- **Data Security**

  Another challenge is data security in cloud computing. The cloud provider can just distinguish the security settings indirectly, and do not having knowledge whether it is totally executed or not. So it is very difficult to form a trust procedure at every cloud architectural layer.

- **Fault tolerance**

  While moving multiple datasets from one place to another there will be a higher risk of occurring a failure in between the process.

1.7 DVFS

To concentrate the Power consumption of data centers the Simulators are currently used. In fact, the expanding utilization of data centers and the high measure of power requested by them, make the investigation of their power consumption to tremendously essential. A few measurements to assess their proficiency are broadly utilized and research is progressing to discover better approaches to lessen energy utilization and enhance energy productivity measurements [11]. This prompts change as well as production of new algorithm that require broad testing stages to approve their adequacy.

Testing and advancement of algorithms in each period are long because of numeral attempts needed to evaluate and enhance the execution. On the approval phases, genuine platforms can be utilized. However it includes important physical estimations and preparation time are not generally conceivable or simple to get and replicate, contingent upon the accessible apparatus. Thus, test systems are normally utilized in this area.

This paper concentrates on the correlation among power aware simulations and real experiments, particularly utilizing Dynamic Voltage and Frequency Scaling (DVFS). This correlation manages the issue for picking a simulator which provides tools for some power aware modeling, how to approve its new functions on the basis of energy consumption and how to enhance it lastly how to utilize it to lead precise simulations.

Energy aware tools are the solutions which can be utilized at various levels, permitting lowering of the power utilization of each and every host in the data centers. A few arrangements operate on the network or on host [12].

The previous solution, called ON/OFF Expectation degree strategy, which switched off the hosts that are not in use and turn it ON if it necessary [53]. All procedures executed on an underutilized host are migrate to different hosts, and afterward the underutilized have is turned off. On the other hand, when every one of the hosts are over-used and the request is high, at least more than one hosts are turned ON again [14]. This procedure has just a single objective, which is to decrease the quantity of turned on hosts on a given time.

As depicted above, its sometime important to utilize migration systems to move different processes among hosts. Migration permits exchange of a working virtual machine from one host to other [15]. These exchanges are not free as far as energy consumption, as every transfer needs some amount of time where information is exchanged amongst source and destination. This strategy permits the arrival of a few hosts and their deactivation, while the remaining running hosts can be utilized at their greatest potential.

Ultimately, Dynamic Voltage and Frequency Scaling (DVFS) can dynamically adjust the frequency and voltage of host's CPU on the basis of load. DVFS can be operate in five distinct modes: User-Space, Conservative, On Demand, Power Save and performance. Three of these five modes, on demand and conservative have a dynamic performance [16]. Power Save utilizes the least recurrence and the User Space mode permits the client to pick one of the accessible frequencies for the CPU. The two keep going modes, Conservative and On Demand, have a dynamic conduct. It implies that the CPU recurrence can fluctuate over time with respect to the CPU request. The governors of the two modes work with limits and timely check if the

CPU load is below (or above) these edges before settling on the choice to change the CPU recurrence. Conservative senator works with an up limit and a down edge. At point when the CPU load is over the up limit the frequency is expanded, and when the CPU load is underneath the down edge the CPU recurrence is diminished [17]. This mode is dynamic, and every CPU recurrence change is performed at one stage step utilizing all accessible frequencies. The On Demand mode utilizes just a single limit and supports framework execution by specifically setting the speediest recurrence when the CPU stack surpasses the edge [18]. A diminishing CPU recurrence, performed at ventures as in the Conservative mode, is performed if the CPU stack remains underneath the limit for a predefined measure of time.

A lesser frequency, which suggests a weaker voltage, diminishes CPU control utilization additionally backs off the CPU calculation limit. As to time went through with I/O operations, the proficiency of DVFS relies on upon the framework design. At times, it additionally backs off the I/O time when DVFS influences the recurrence of the FSB (Front Side Bus) [19]. On the off chance that a recurrence change just influences the multiplier between the FSB and the CPU recurrence, I/O execution is not influenced.

1.8 DVFS IN CLOUDSIM

The main functionality of DVFS simulation is being added to another package, named as DVFS. In the package, governors of the five methods of DVFS, were executed. Their part is to decide whether the frequency of the CPU must be altered and their choice is straightforwardly related to their intrinsic decision rule. In the test system, a frequency may alter dynamically effects the capacity of CPUs, measured in MIPS [20].

The utilization of DVFS straightforwardly influences the execution of the CPU limit, which are liable to normal conversion during simulation. This additionally includes changing the way the test system holds the management and arrangement of virtual machines [21]. For instance, if the framework chooses to diminish the frequency, the total of limits of every single virtual machine may incidentally cross the maximum limit of the host. For the situation, the extent of any virtual machine should incidentally be balanced descending in extent to the limit of the new host. A similar circumstance happens when at least one new virtual machines must be combined to a host as of now being used [22].

Likewise, when some portion of capacity for a host is free, limits of virtual machines still active may increment. This occasion happens when the CPU frequency is expanded or when a virtual machine has completed its execution. For this situation, the limit of all the waiting virtual machines are scaled up in regards to the free limit of the host, while taking consideration to don't surpass its most extreme limit [23].

The consideration of DVFS in CloudSim needs modifications in the management of events executed by the simulation core [24]. Actually, the PowerSave mode prompts a delay in the execution of assignments as the CPU works at its lower frequency. Under these conditions, the development of successive events ought to be specifically connected with the end of every event [25].

1.9 WORKFLOWSIM-DVFS ENTITIES FUNDAMENTALS

Workflowsim expands Cloudsim for the purpose of processing workloads and DAX workflows in which tasks have complex interdependencies between them [26]. There are five entities that conduct the workload management in workflowsim-DVFS:

- The planner
- The Merger
- The Engine
- The Scheduler
- The Datacenter

The Planner is the substance that instates the system and parses the DAX document to get the separate tasks called Cloudlets [27]. At that point, those tasks are being sent to the Merger that collaborate the various tasks into jobs. The default setup of the simulators leaves no clustering performed; it normally gets every tasks into jobs separately. After that, the jobs are being sent to the Engine, in which they are chosen taking after the order determined by the workflow [28].

The Engine make sure that workflow order is being followed and sent it to the Scheduler the tasks that needs to be prepared each time an assignment is returned. At long last, the Scheduler chooses which VM of the Datacenter is the most appropriate for preparing each task Interchanges are gathered in three phases:

- **Initialization Stage:**

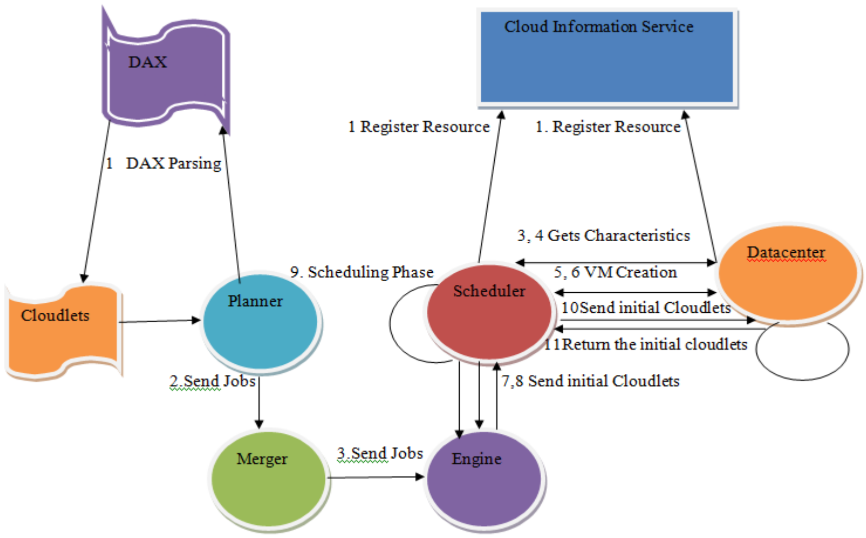


Figure 1.7: Initialization stage [14].

- **Main Stage**

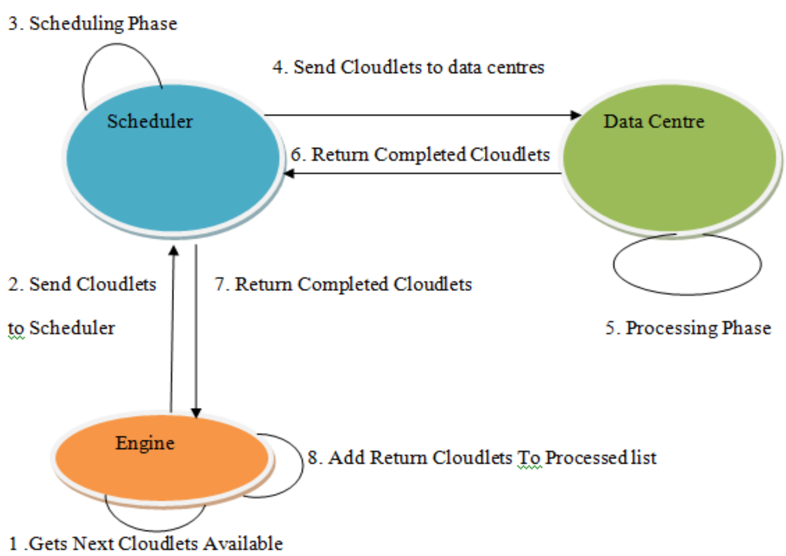


Figure 1.8: Main stage [16].

- **Ending Stage**

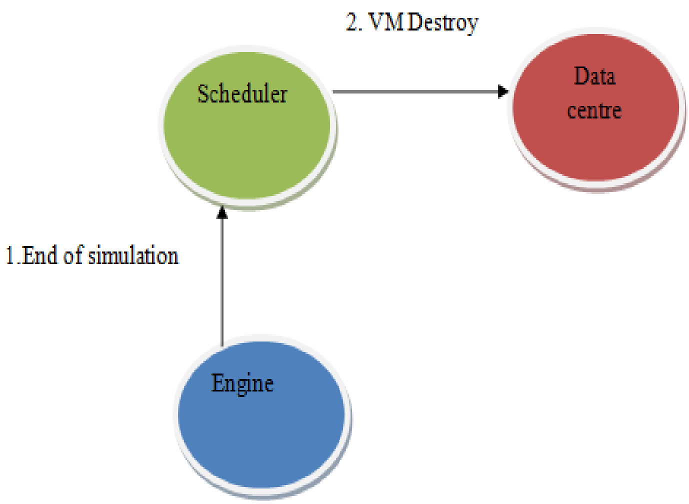


Figure 1.9: Ending stage [15].

The procedure is repeated for main stage every time the Datacenter ends the task processing. This might be notify that to make the near the behavior of power aware and genuine datacenter using workflows [29]. Scheduler must not exclusively have the capacity to utilize data identified with execution times additionally, energy and power parameters, and besides, the hosts inside the Datacenter must incorporate DVFS governors [30].

Ultimately, Dynamic Voltage and Frequency Scaling (DVFS) can dynamically adjust the frequency and voltage of host's CPU on the basis of load. DVFS can be operate in five distinct modes: User-Space, Conservative, On Demand, Power Save and performance. Three of these five modes, on demand and conservative have a dynamic performance.

CHAPTER 2

REVIEW OF LITERATURE

Service providers are facing various scheduling issues while deploying the scientific workflow in cloud environment. Taking into consideration the issue, following review of literature has been conducted.

Table 2.1: Review on scheduling algorithms for scientific workflow in cloud computing

Author	**Year**	**Title**	**Approach**
Xu, Meng et al.	2009	"A multiple QoS constrained scheduling strategy of multiple workflows for cloud computing"	Design algorithm to schedule multiple scientific workflows. The high computing jobs given highest priority.
Pandey et al.	2010	"A particle swarm optimization-based heuristic for scheduling workflow applications in cloud computing environments"	PSO based heuristic has been designed. The focus of research toward minimizing the computation and communicational cost of scientific workflow.
Mezmaz et al.	2011	"A parallel bi-objective hybrid meta heuristic for energy-aware scheduling for cloud computing systems"	Makespan time reduction effort done by the author. Energy consumption optimization technique is also used in the scheduling.
Rizvandi et al.	2011	"Some observations on optimal frequency selection in DVFS based energy consumption"	Proposed slack reclamation algorithm by accessing the power reduction problem from an alternate angle.
De Oliveira et al.	2012	"A provenance-based adaptive scheduling heuristic for parallel scientific workflows in clouds"	Adaptive approach has been introduced to execute workflow in parallel. Factors considered as: Cost, reliability and time.
Zhen Xiao et al.	2012	"Automatic scaling of internet applications for cloud computing services".	Significant semi-online color set algorithm used that is being capable of achieving good demand satisfaction ratio and can be able to saves energy by lessen several servers used when the load is relatively low.

Peter et al.	2012	"A constraint based resource discovery model for multi provider cloud environments".	A two stage resource choice model is used for utilizing a limitation based approach which empowers clients to coordinate their applications prerequisites to infrastructure resources.
Abrishami et al.	2013	"Deadline-constrained workflow scheduling algorithms for Infrastructure as a Service Clouds"	Partial Critical Path (PCP) method has been used for the scientific workflow scheduling. Deadline is another important constraint considered in this paper to schedule large scientific workflows.
Guérout et al.	2013	"Energy-aware simulation with DVFS: Simulation Modeling Practice and Theory"	DVFS is used to make comparison between the real experiments and the simulators.
Zhang et al.	2014	"Multi-objective scheduling of many tasks in cloud platforms"	Ordinal optimization (OO) algorithm is used for workflow scheduling for bi-objective. Author focus toward reducing scheduling overhead.
Poola et al.	2014	"Robust Scheduling of scientific workflows with deadlines and budget constraints in clouds".	The RCT strategy contributes a robust schedule with expenses hardly higher than the reference algorithm investigated. Their strategies give robust schedule with an insignificant makespan.
Jen-Hsiang et al.	2014	"A hybrid model for cloud providers and consumers to agree on QOS of cloud services".	The proposed agenda that is based on preferences ordering approach which helps providers and consumers to reach agreement over the issues and built a common reference sequence to enhance the efficiency of issue negotiation.
Wang et al.	2014	"Workflow as a Service in the Cloud: Architecture and Scheduling Algorithms"	proposed the workflow as a service (WfaaS) architecture. To make it scalable and expandable, this architecture is being designed.
Qishi et al.	2014	"End to End Delay Minimization for Scientific Workflows in Clouds Under Budget Constraints"	discussed about the development of prototype generic workflow system using influence of existing technologies for rapid calculation

			of scientific workflow optimization strategies..
Malawski et al.	2015	"Scheduling multilevel deadline-constrained scientific workflows on clouds based on cost optimization"	AMPL and CMPL is used for the cost optimization.
Yong Zhao et al.	2015	"A Service Framework for scientific workflow management in the cloud"	The author combine swift workflow management system to the Open Nebula and eucalyptus cloud platforms in which cloud resource manager,
Amelie Chi et al.	2015	"A Declarative Optimization Engine for Resource Provisioning of Scientific Workflows in IaaS Clouds"	Author proposed a best engine called Deco i.e for resource provisioning in IaaS clouds.
ul Islam et al.	2015	"Hybrid DVFS Scheduling for Real-Time Systems Based on Reinforcement Learning"	Hybrid DVFS approach is used to save energy.
Weiwei et al.	2015	"Dynamic and Fault Tolerant Clustering for Scientific Workflows"	This framework maximum likelihood estimation-based parameter for modeling workflow performance.
Zhuo et al.	2015	"An Energy-Efficient Task Scheduling Algorithm in DVFS-enabled Cloud Environment"	The amount of randomly generated DAGs workflows, the experimental results show that DEWTS can reduce the total power consumption.
Xiu Li et al.	2015	"A scientific workflow management system architecture and its scheduling based on cloud service platform for manufacturing big data analytics"	This paper includes Maximum Percentage algorithm. With respect to load balancing level and total completion time, this algorithm gives better performance.
Ghafarian et al.	2015	"Cloud-aware data intensive workflow scheduling on volunteer computing systems"	Figure portioning of DAG has been used to balance the size partitioning. It is only working on reducing data frequency but not considering the data size. Not suitable for data intensive workflows.
Jianbing Dinga	2016	"Auction Based cloud service	talks about Abacus. It is auction

		differentiation with service level objectives”	based resource assignment framework which is for cloud computing. It gives effectual service difference with several budgets and priorities for jobs.
Cotes et al.	2016	"Dynamic Voltage Frequency Scaling Simulator for Real Workflows Energy-Aware Management in Green Cloud Computing"	Author proposed a new tool that collaborates power model on the basis of communication design and computing and uses the DVFS
Zhao et al.	2016	“A new energy-aware task scheduling method for data-intensive applications in the cloud”	Energy aware task scheduling algorithm is designed using clustering and effective data placement.

Xu, Meng et al. (2009) has devised the scheduling algorithm for multiple workflow for cloud computing. The author focused on the covariance of time and cost, in which surplus of time and cost has been discussed. Scheduler first does the preprocessing of jobs then scheduling and final execution of the jobs. QoS constraints are considered in the scheduling. The preprocessor evaluate the parameters of workflow. After the completion of task notification has been initialized. The algorithm has been compared with algorithm and provides significant improvement [30].

Pandey et al. (2010) proposed the PSO (particle swarm optimization) that is based on scheduling algorithms. PSO is an intelligent algorithm working on social behavior such as bird finding their food and fishes protect themselves from predators. Heuristics has been designed to reduce data transmission cost and the computation cost. The comparison done with BRS (Best Resource Selection) has done. It shows the significant improvement. Performance of algorithms is highly depends on the fitness value. Generic heuristic is designed which can be used on small to big data centers. The number of particles can be increased and given the number of resources. The PSO heuristic algorithm proves three times improvement than BRS algorithm [31].

Mezmaz et al. (2011) investigate the meta heuristic scheduling algorithm for energy optimization for cloud environment. The genetic algorithm based parallel bi-objective used to reduce the make space as well as energy consumption. The proposed algorithm considers the dynamic voltage scaling (DVS) method for energy optimization. GA selects the solution from the population. The solution further replaced by new solution randomly or by any selecting criteria. Hybrid genetic algorithm has been designed using energy-conscious scheduling (ECS). The experiments depict algorithms give performance better than DBUS and HEFT algorithms [32].

Rizvandi et al. (2011) proposed slack reclamation algorithm by accessing the power reduction problem from an alternate angle. Primarily, the issue of undertaking slack recovery by utilizing mixes of processors' frequencies is planned. Also, a few confirmations are given to demonstrate that (1) If the running frequency recurrence set of processor is thought to be proceeds with, the ideal power will be dependably accomplished by utilizing just a single recurrence (2) for actual processors with a discrete arrangement of working frequencies, the ideal power is constantly accomplished by utilizing at most two frequencies and (3) these two frequencies are nearby/neighboring when processor vitality utilization is a curved capacity of recurrence [33].

de Oliveira et al. (2012) proposed a dynamic scheduling algorithm in virtual VM cluster. Hadoop is used for parallel execution of scientific workflow. Author devised static scheduling algorithm for low performing application, but this may not work for high performance computing (HPC). As cloud computing is supporting the elasticity feature and work with static allocation is not properly using the elasticity feature of cloud. Adaptive algorithm has been designed to work with resources demand varies with time. The author works on data intensive workflow applications. In future, they proposed to work on fault tolerance based dynamic scheduling for data intensive scientific workflow applications [34].

Qi Chen et al.(2012) proposed a system to the internet application that gives automatic scaling to it in cloud environment. For purpose of providing fault isolation author use virtualization technology that contain every application instance in virtual machine. It is named as CCBP (Class Constraints Bin Packing) problem in which every class is application and every server is a bin. Author forms an significant semi-online color set algorithm that is being capable of achieving good demand satisfaction ratio and can be able to saves energy by lessen several servers used when the load is relatively low [35]. In this paper, the multiple generation of hardware is being divided into equivalence classes in data centres and run algorithm in every class. In future, he will expand the system to hold differentiated services and also grant fairness in distributed resources within the applications. In future, the efficient algorithm will be developed to allow incoming request within the set of compatible classes.

Peter Wright et al. (2012) proposed a cloud infrastructure provider that provides cost effectual and extremely flexible resources for use. This infrastructure commercial centre is growing quickly with new suppliers, infrastructure items and quality included services going to the business sector. But the biggest challenge is mapping an application's necessities onto an arrangement of resources. Author built up a two stage resource choice model utilizing a limitation based access that empowers clients for coordinate applications prerequisites the resources of infrastructure [36]. This model basically focuses on the application rather giving focus on resources. This methodology is generally connected in a two-stage way that empowers clients to choose suitable resources and afterward adjust the necessities of the application framework with practical furthermore, non-practical necessities.

Abrishami et al. (2013) devised two algorithms based on partial critical path (PCP) that has ability to decrease the cost of workflow execution. One-phase and two-phase algorithms are designed with deadline distribution. Sub-deadlines are assigned by the parent algorithm over the scheduling of service. The deadlines are assigned to all unallocated nodes. Path assigning algorithm is taking path as input and also assigns deadlines to each node. The difference among the latest finish time and earliest start time is the path sub-deadline. Planning algorithm is used for completion of tasks which select the cheapest resources for task before its sub deadlines [37]. If existing instance is not met the criteria, new instance has been initiated. The application such as Montage, LIGO, Cybershake etc. are used for the experiment. The algorithm reduces the computation time.

Guérout et al. (2013) portrays tools that can support power aware experimentation on simulator. The DVFS simulation is used, from its execution in the simulator CloudSim to the entire approach is being adopted to approve its working. Moreover, a logical application is utilized as an utilization case in both utilizations and experiments, where the connection between hardware and DVFS efficiency is highlighted [38].

Zhang et al. (2014) tailored a multi-objective algorithms based on ordinal optimization (OO) for complex dynamic cloud environment. OO technique is combined with virtual cluster from the multi datacenters named as VOO. Blind Pick and Monte Carlo methods are used to search the optimal resource in previous algorithms used for the comparison [39]. Experiment has done on LIGO scientific workflow application and proves that this is first multi objective algorithm and provides significant benefit in scheduling of jobs and save half of the time from searching.

Poola et al. (2014) devised three resource allotment policies that is related to cost, robustness and make span as its objective. For making the schedule robust by considering the budget and deadline constraint, the resource allotment policies adds slack time to it. Results shows that these policies are being robust against doubts like performance variations and task failures of virtual machine. With the proposed strategies introduced, the RTC arrangement demonstrates the maximum robustness and in the meantime reduces makespan of the workflows. The RCT strategy contributes a robust schedule with expenses hardly higher than the reference algorithm investigated. The weights of the weighted approach can be changed by client needs [40]. Their strategies give robust schedule with an insignificant makespan. They additionally demonstrate that with increment in budget, their approaches expand the robustness of schedule with sensible increment in cost.

Jen-Hsiang Chen et al. (2014) talks about the issues based approach that facilitates the several issues negotiation process in between service providers and service consumer on the Quality of service requirements. Negotiation is the discovering process for agents that take part to reach an agreement that is being acceptable [41]. The proposed agenda that is based on preferences ordering approach which helps providers and consumers to reach agreement over the issues and built a common reference sequence to enhance the efficiency of issue negotiation. By the growing popularities in E-business there is need of semi automated and automated search process that can enhance efficiency to resolve conflicts. In this research paper, the author proposed efficiency and performance methods to help decision maker to choose the application according to their needs. In this author varies the different parameters in constraints and utility functions and the results has the strong impact on patterns. This result is being derived from the designed rules which permit profit to be transfer among the issues

Jianwu Wang et al. (2014) proposed the workflow as a service (WFaaS) architecture. With more workflow frameworks receiving cloud as their execution environment, it gets to be growingly difficult on how to systematically manage workflow execution on VM occurrences, different workflows and virtual machines (VMs). To make it scalable and expandable, this architecture is being designed. Depending upon the several goals, author proposed four heuristic workflow algorithms for scheduling architecture. Author differentiates this algorithm and perform some experiments on the basis of price/performance ratio, monetary cost and process time. It is being found if the algorithm is done with proper configuration then it can minimize both price/performance ratio and cost without effecting performance. In future, the author decided to improve algorithm that can support more complex workflow logics so that it can support the algorithm in physical cloud environment with real applications in bioinformatics [42].

Chase Qishi Wu et al. (2014) discussed about the development of prototype generic workflow system using influence of existing technologies for rapid calculation of scientific workflow optimization strategies. They also built an analytical model that counts the network performance. They used cloud based computing resources. What’s more, define an undertaking booking issue to minimize the work process end-to-end delay under a client indicated money related limitation. They thoroughly demonstrate that the proposed issue is NP-complete as well as non-approximable. They plan a heuristic answer for this issue, and show its execution predominance over existing strategies through vast simulation also, genuine work flow tests in view of evidence of-idea execution and arrangement in a local cloud tested [43].

Malawski et al. (2015) present the model based on mathematical programming language a Mathematic Programming Language (AMPL) and Coin Mathematical Programming Language (CMPL) used to minimize the cost of workflow execution by taking consideration of deadline. Algebraic mathematical models used to define variables, constants. It provides good optimization algorithm for linear, non-linear models. Application and infrastructure models are used as direct acyclic graph (DAG) by considering the large scale system. Large workflow is sub-divided into various parts and each one is not depend on another part. Mixed integer problem (MIP) is used along with mathematical model [44]. The model gives significant benefit for application level benchmarking for actual application performance.

Yong Zhao et al. (2015) talks about the scientific workflow management system in cloud computing. As cloud computing provides scalability and resources on demand. So for managing large increasing data and complexity, it is necessary to migrate scientific workflows in cloud so that it can handle this large amount of resources, data provisioning, data dependencies and so forth. For this purpose the author purpose a reference service framework for combining scientific workflow management system to the different cloud platforms that will be important for handling and provisioning of virtual resources in the cloud [45]. As for the purpose of migrate it into cloud, the author combine swift workflow management system to the Open Nebula and eucalyptus cloud platforms.

Amelie Chi Zhou et al. (2015) talks about the scientific workflows resource provisioning in IaaS. It is an essential and complex problem for optimize performance and budget of workflows. Many scientists are being facing the problem that results from critical cloud performance. By finding this issue, Author proposed a best engine called Deco i.e for resource provisioning in IaaS clouds. It allows clients to define workflow optimization goals and compulsion of specific problem with an extended declarative language. This declarative engine gives a set of functional construct as building pieces to encourage clients to create resource provisioning instruments for workflows [46]. In addition, a novel methodology of probabilistic advancements on objectives and limitations is created to address cloud dynamics.

ul Islam et al. (2015) proposed the Hybrid Approach .Energy utilization is one of the toughest challenge for construction of current computing system. In every computing device, processor utilizes the maximum amount of energy utilization as compare to other components. So to minimize energy utilization DVFS is mainly used in processors [47]. The real time DVFS techniques work great under various conditions but only algorithm does not always best under various workloads, power settings and dynamic slacks. Farthermost, the deviation in system configuration influence the suitability of DVFS algorithm. In this paper author proposed learning based approach that takes various previous techniques to handle homogeneous conditions.

Weiwei Chen et al. (2015) proposed theoretical analysis is conducted in which the analysis is of impact of transient failure on runtime performance of scientific workflow execution. To improve runtime performance of workflow execution they suggest three fault tolerant clustering strategies which work in faulty execution environments. Results for experiment demonstrated that the proposed strategies essentially enhance the work flow make span when contrasted with a current task clustering technique utilized as a part of work flow management frameworks. Furthermore, they propose a dynamic tasks clustering technique to upgrade the work flow make span by powerfully modifying the clustering granularity while arising of failure [48].

Zhuo et al. (2015) proposed a DVFS- allows Energy-efficient Workflow Task Scheduling algorithm: DEWTS. DEWTS can use the helpful slack time repetitively after servers are combined. Firstly it computes the task's initial scheduling order and get the entire makespan and deadline depends on Heterogeneous-Earliest-Finish-Time (HEFT) algorithm [49]. Through turning the processors with their energy utilization and running task number, the underused processors can be converged by shutting the last hub and redistributing the assigned tasks over it. At long last, in the task slacking stage, the tasks can be scattered in the free slot under low frequency and voltage by using DVFS.

Xiu Li et al. (2015) proposed the scientific workflow management system architecture depending upon the cloud manufacturing service platforms. The new developed technologies, for example, cloud computing furthermore, web of things are being considered and the bottlenecks is a problem that is being faced by the organizations in assembling big data analytics are examined. But the biggest issue in workflow system is scheduling algorithm. This paper includes the existing problems related to the scheduling algorithm as an inspiration to offer a novel scheduling algorithm named as Maximum Percentage algorithm. With respect to load balancing level and total completion time, this algorithm gives better performance. In future the author will carry out experiments in complicated and dynamic environment to test the algorithm [50].

Jianbing Dinga et al. (2016) talks about Abacus. It is auction based resource assignment framework which is for cloud computing. It gives effectual service difference with several budgets and priorities for jobs. They develop auction mechanism which is very effective. Abacus as of now just handles independent calculation resources in the framework. So there can be the future work in which the dependent resources can be handled. This can be done by using dependent model [51]. Hence, another theme for future study is to analyze the convergence speed theoretically. During the resource allocation, it will be more challenging to separate dependent resources. It will be difficult to sketch mechanism of resource allocation for complex cloud applications.

Cotes et al. (2016) proposed a new tool that collaborates power model on the basis of communication design and computing that permit the atomization of advanced management strategies in power saving in the consideration of network cost, computing, reconfiguration, Quality of Service and also associate Dynamic Voltage Frequency Scaling (DVFS). This simulator is created to be compatible in various real time schemes and also invokes wide range of DVFS governors. So the output shows how much amount the simulator is valid on the basis of frequency, voltage scaling energy, resource utilization and time saving [52].

Zhao et al. (2016) devised a new offline task scheduling method in cloud was suggested in order to decrease consumption of energy. The ultimate goal of this work is to furnish a scheduling framework with high energy efficiency and low rate of SLA violation for data- intensive applications. The data sets and cloud system were built into a hierarchal tree like structure by clustering which is based on data correlation. Hence, the amount of movements of globalised data can be reduced, which further can minimize the SLA violation rate and enhance energy efficiency in the cloud (servers and network devices). Moreover a model for energy consumption was designed [53]. Then essential parameter Task Requirement Degree (TRD) was proposed by which resource utilization efficiency can be improved. In the time ahead, optimization algorithms will be researched based on evaluation function to gain higher energy efficiency.

CHAPTER 3

PRESENT WORK

3.1 PROBLEM FORMULATION

Various researchers are working time to time to optimize the scheduling of task as per the nature of task, application and environment. The data centers are consumed huge energy and this ratio is increased as per the establishment of new datacenters. Much energy aware scheduling methods have already developed, as per the literature review done, no robust energy aware scheduling algorithm has been developed. As algorithm save the energy, on other hand they violate the SLA, due to which data center providers, has to pay penalty to the users. Existing algorithm is doing offline scheduling of jobs which compromise the SLA while saving the energy. VM sharing strategy applied in this research work can further improve to save the energy consumption in cloud environment.

3.2 OBJECTIVE OF THE STUDY

Therefore following objectives has been devised:

1. To cluster the scientific workflow task as per hierarchical task clustering.

2. To design and develop the energy aware scheduling algorithm for data intensive workflow in cloud environment.

3. To analyze the proposed scheduling algorithm with existing algorithm based on energy consumption and SLA violation**.**

CHAPTER 4

RESEARCH METHODOLOGY

To achieve the objectives following methodology has been devised.

4.1 CLOUD ENVIRONMENT MODEL

The scientific workflow is considered to be executed in geographically distributed area. The datacenters considered for the cloud are of heterogeneous environment such as different energy consumption criteria, network bandwidth and different storage and computation capacity. To achieve the above objective network bandwidth and computational capacity is considered.

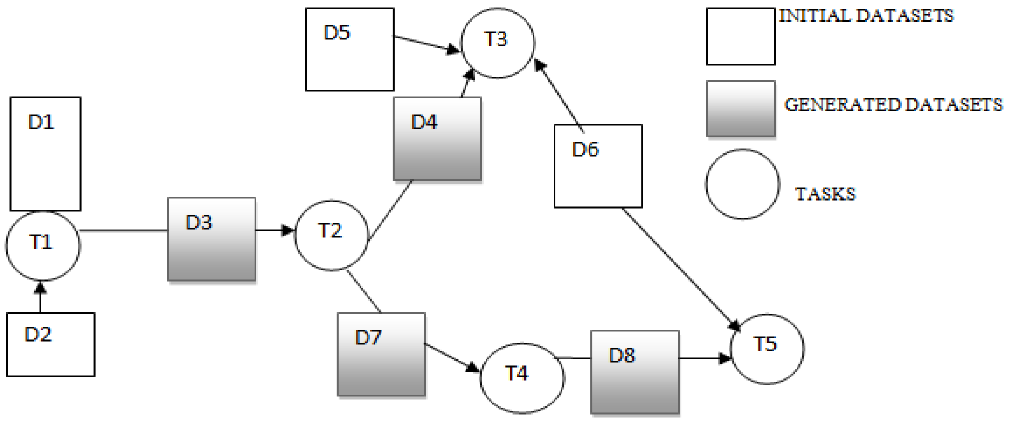


Figure 4.1: Workflow model [12].

4.1.1 NETWORK STRUCTURE MODEL

Data transmission on high speed network channel can reduce the transmission time. It also reduces the SLA violation for the user. To achieve the mentioned objectives, hierarchical clustering of jobs will be done as per the network condition.

$$B = \begin{bmatrix} b_{1,1} & b_{1,2} & \cdots & b_{1,|S|} \\ b_{2,1} & b_{2,2} & \cdots & b_{2,|S|} \\ \vdots & \vdots & \cdots & \vdots \\ b_{|S|,1} & b_{|S|,2} & \cdots & b_{|S,|S|} \end{bmatrix} \quad \text{....(i)}$$

To convert the cloud system to tree structure the recursive function on B matrix will applied. The partition of matrix will be done as the complete system converted to tree structure as per the following equation.

$$PM = \sum_{i=1}^{p} \sum_{j=1}^{p} b_{i,j} \cdot \sum_{i=p+1}^{|S|} \sum_{j=p+1}^{|S|} b_{i,j} - \left(\sum_{i=1}^{p} \sum_{j=p+1}^{|S|} b_{i,j}\right)^2 \quad \text{.....(ii)}$$

.

Virtual machine placement: During virtual machine placement number of VM allocated to host depend upon the capacity of the host. Researcher must satisfy the resource so host as well as the number of VM on the host.

4.2 SERVER ENERGY CONSUMPTION MODEL

The server consumes almost 50 percent of their peak power. Author [base paper] is working on two approaches; first if the VM is under loaded than assign the more task to the machine, second method is migration of task to other machine and shutdown the machine.

In the proposed research methodology, researcher is going to extend this technique using dynamic voltage fluctuation system (DVFS). By using DVFS, if further migration is not possible or the number of task running on the machine is going to complete, than migration can further reduce the performance.

By using DVFS the voltage given to under loaded machines can be reduced which further optimize the energy consumption to next level. By using the above method, effective utilization can be optimized. VM sharing and dynamic voltage is effective techniques. Global energy consumption will reduced to significant level. Improved task allocation technique can further improve the VM sharing.

4.3 TASK ASSIGNMENT METHOD

Objective of the research work is energy efficient task scheduling of scientific workflow applications. In order to achieve the objective, the first attempt is to reduce the data transmission among the data centre. Many existing techniques are work on energy optimization, but it lead to SLA violation. Some techniques are assigning more computation power to the application, but if the network bandwidth is not appropriate than there is a wastage of the computation resources.

4.3.1 CORRELATION BASED CLUSTERING

Complex dependencies exist in between the scientific workflow applications. Data intensive application correlation matrix design is different from the classical methods, because the frequency of dataset is less than the amount of data. Following step will be followed for the correlation based matrix design.

Step 1: Correlation of Initial data sets.

Step 2: Drive correlation of intermediate datasets.

4.3.2 HIERARCHICAL CLUSTERING

It is used for the dataset that is mutual dependent. Calculation of in-depth correlation will be done for the hierarchical clustering. The result of hierarchical clustering is binary tree.

After the clustering, the Power consumption strategy has been applied on the task to allocate the server to the task. Threshold based strategy has been applied for taking decision for task assigned. Task requirement degree (TRD) calculation strategy is depend on on-off expectation degree (OOED).

Step 1: If the mean effective utilization of VM is lower than threshold and it is for more than one machine. Than count the number of task on both the machine, if it can be assigned to one machine than migrate the task of machine having less number of task and also assign new task to first machine and shutdown the second one. If the number of task on both the machines are more and cannot accommodate on one machine than apply DVFS.

Step 2: If the upcoming workflow load is at high frequency than do not migrate any jobs and assign the new jobs to the running machines.

4.4 ROBUST SCHEDULING STRATEGY

The server and the task has been modelled to tree structure. Highly associated task must place on same node, so that data transmission cost and time can be reduced. If in case both cannot be placed on same place, the attempt should be made to place the task on nearby nodes. Proposed task scheduling strategy is:

Step 1: Select the task from the waiting queue.

Step 2: Calculate the TRD. Proposed scheduling strategy has been designed using new OOED method using DVFS. The TRD values decide the task assigned priority.

Step 3: Select the task execution VM for the set of task. Following methods are used for node selection for VM.

Method 1: If the node having highest TRD value, given highest priority while assigning the task.

Method 2: If two nodes having same TRD than select the node with lowest layer in the task tree.

Method 3: By using method 1 and method 2, if still not able to decide the node, than select the node with higher mean TRD.

Method 4: Still if not able to differentiate between the nodes, than select the node which is more energy efficient.

Step 4: After selecting the appropriate node, the VM should be selected from the server VM group. Select the VM which can correlate with the previous task. Initialize the new server if the computation capacity of the server is not enough. Researcher is following same threshold values used by previous technique: CPU and memory utilization upto 70 percent and data amount in the server 50 percent.

Step 5: Allocate the task to the server with next highest priority. This step should be performed recursively till all the task will not be allocated to the VMs.

Step 6: If some task has been failure, do re-clustering of failed task and re-assignment of the failed tasks.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 EXPERIMENTAL RESULTS

5.1.1 SIMULATION SETUP

Workflowsim has been used for implementing the Robust Energy Aware Task Scheduling for Scientific Workflow in Cloud Computing. It is an open source workflow simulator. It is giving a workflow level support by amplifies cloudsim. Workflow will be modeled using DAG model in which DAG model demonstrate a model of delay happening in different levels of Workflow Management System, elaborating model of failure of node, stack and task clustering algorithm. Parameters are straight forwardly gained from hints of genuine execution. Below are the various results gathered during the experiments. Both the existing and proposed results are posted to make a comparison of how our technique performs better in terms of various performance attributes.

5.1.2 APPLICATION MODELING

A workflow is combination of various tasks according to the dependencies. It indicates the temporary relationship between the tasks. The sequence and parallelism performs the task concurrently. Each having their own characteristics.

5.1.3 RESOURCE MODELING

Cloud Model having one dataset is taken. To effectively process the cloudlets without any overhead, four types of VM is used with homogeneous configuration. The actual machine that is available in data centers is host. Proposed algorithm saves the energy and also do not violate the SLA.

Hosts and Virtual Machine each having its own specification that are given in table below:

Table 5.1: Virtual Machines with specification

No of VM Types	4
MIPS	{2500,200,1000,500}
No of Processing element	{ 1, 1, 1, 1 }
RAM	{ 870, 1740, 1740, 613 }
Bandwidth	100000
SIZE	2500

Table 5.2: Hosts with specification

No of Host Types	2
MIPS	{1800,2660}
No of Processing element	{ 2, 2 }
RAM	{ 4096, 4096 }
Bandwidth	1000000
STORAGE	1000000

Table 5.3: Types of VM

High CPU Medium instance	2.5 EC2 compute unit, 0.85 GB
MIPS	2 EC2 compute unit, 3.75 GB
Extra large instance	1 EC2 compute unit, 1.75 GB
Small instance	2.5 EC2 compute unit, 0.85 GB
Micro instance	0.5 EC2 compute unit, 0.633 GB

All the above specifications influence the performance of the technique directly. In VM, to run a task, MIPS is necessary and the available host's MIPS is observed periodically. The DVFS mechanism modifies the supply and voltage on the basis of CPU utilization to minimize the energy consumption. When the usage is very low in order to reduce the power consumption, the voltage will be lowered. On the contrary, when usage is very high it maximize the voltage to meet the quality of service.

Virtual machine is created virtually on the host. To effectively process the cloudlets without any overhead, four types of VM is used with homogeneous configuration. The actual machine that is available in data centers is host.

5.1.4 BASELINE ALGORITHM

Researcher proposed DVFS and compared it with existing algorithm. The data centers are consumed huge energy and this ratio is increased as per the establishment of new datacenters. As algorithm save the energy, on other hand they violate the SLA, due to which data center providers, has to pay penalty to the users. Existing algorithm is doing offline scheduling of jobs which compromise the SLA while saving the energy but proposed algorithm saves the energy and also do not violate the SLA.

5.2 COMPARISON WITH EXISTING TECHNIQUE

Previously, the genuine power utilized by datacenters is measured by varying the two main parameters: Number of VM and Number of Hosts. After that the same scenario is being conducted with the DVFS deployment. Every Scenario has variety of observations that will differ according to no. of hosts and no of VM. In this, it is being considered the energy consumption experienced by proposed algorithm, SLA and no. of VM migration. As the performance of proposed algorithm is better because it consumes less energy as well as do not violate the SLA as compare to existing technique. Researchers have taken different scenarios with different number of Virtual Machines and different number of hosts to check the performance.

5.2.1 SCENARIO 1

Energy consumption for existing, proposed and non power aware algorithm is compared side by side to show the difference.

Consider the first scenario with 5 Hosts and 5 Virtual machines and simulation limit= 24*60*1 and find out the variation in power consumption and also figure out the performance of DVFS mechanism.

Table 5.4: Comparison with existing technique in Scenario 1

Algorithm	SLA	Energy Consumption	No of VM migration
Non Power Aware	0.000	0.21	0
Existing	0.00272	0.17	4
Proposed	0.000	0.16	0

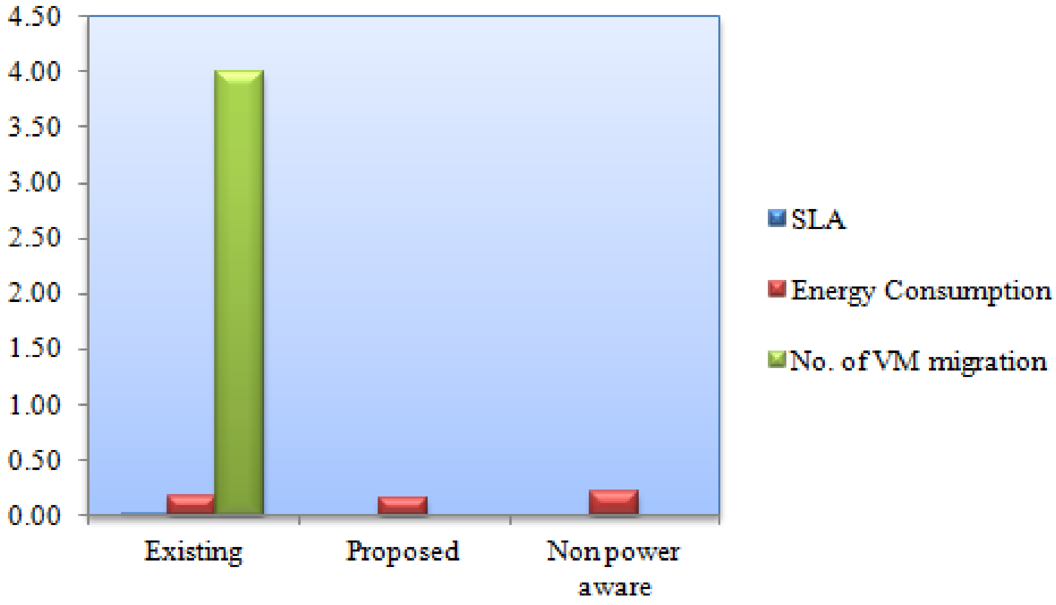


Figure 5.1: Comparison with existing and non power aware as per Scenario 1

The energy consumption is measured in kwh which are accurate enough to compare. On the basis of results, the when no. of host and no of virtual machines are same then energy consumed in existing algorithm is more and also violate the SLA whereas energy consumption is less with the deployment of DVFS. As it uses only those host machines that are needed rest will not be running to save the power.

5.2.2 SCENARIO 2

Now second scenario, it is being taken 5 Hosts and 5 Virtual machines and simulation limit= 24*60*60 and find out the existing, Proposed and non power aware algorithms.

Table 5.5: Comparison with existing technique in Scenario 2

Algorithm	SLA	Energy Consumption	No of VM migration
Non Power Aware	0.000	14.85	0
Existing	0.01635	11.60	348
Proposed	0.000	11.5	0

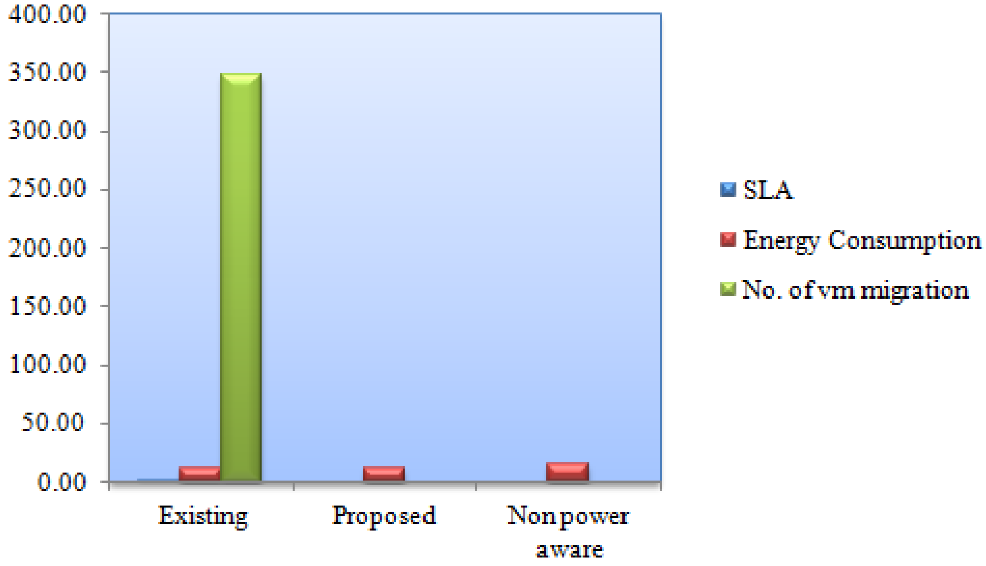


Figure 5.2: Comparison with existing technique as per Scenario 2

When the no. of host and no. of VMs are same but take simulation limit for whole day i.e 24*60*60 then see the no of VM migration are much more in existing whereas there is no VM migration in DVFS mechanism and also energy consumed in existing is more as proposed algorithm.

5.2.3 SCENARIO 3

Now in the third scenario, Number of host is doubled i.e 10 and no. of VMs kept constant i.e VM=5, Simulation limit=24*60*1 and find out the variation in power consumption and also figure out the performance of DVFS mechanism.

Table 5.6: Comparison with existing technique in scenario 3

Algorithm	SLA	Energy Consumption	No of VM migration
Non Power Aware	0.000	0.42	0
Existing	0.00272	0.32	4
Proposed	0.000	0.31	0

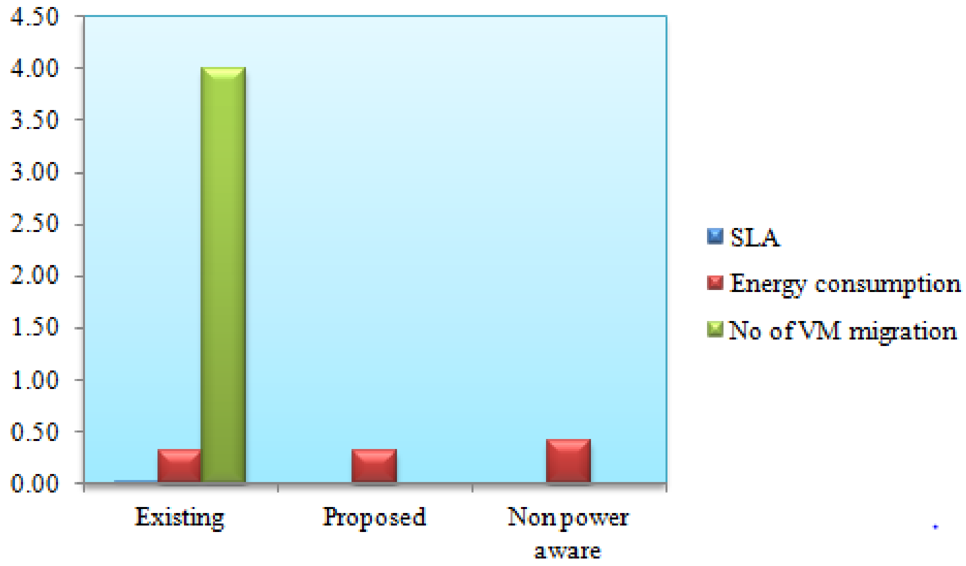


Figure 5.3: Comparison with existing technique as per scenario 3

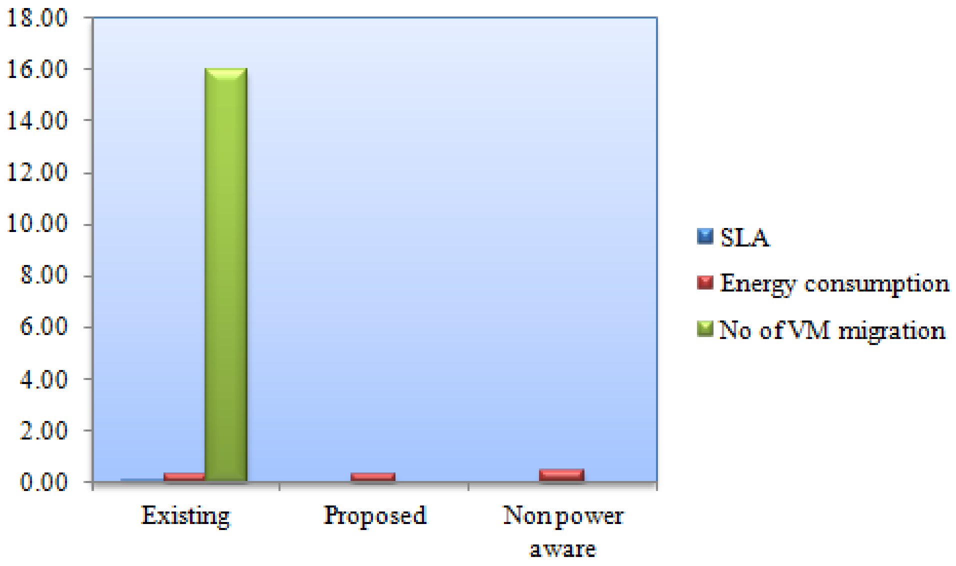
On the behalf of results as shown in above graph, when no. of host and no. of virtual machines are different then energy consumed in existing algorithm is more and also violate the SLA whereas energy consumption is less with the deployment of DVFS. As it uses only those host machines that are needed rest will not be running to save the power. So when different number of host and virtual machine is there then DVFS gives better results in terms of SLA and Energy consumption.

5.2.4 SCENARIO 4

In the fourth scenario, consider the 10 hosts, 10 Virtual Machines, 24*60*1 Simulation limit and find out the variation in power consumption in existing, Proposed and non power aware algorithm and also figure out the performance of DVFS mechanism.

Table 5.7: Comparison with existing technique as per Scenario 4

Algorithm	SLA	Energy Consumption	No of VM migration
Non Power Aware	0.000	0.42	0
Existing	0.07268	0.33	16
Proposed	0.000	0.32	0



.**Figure 5.4:** Comparison with existing technique as per Scenario 4

As the results shows that if the number of hosts and virtual machines are increased then energy consumed by existing and non power aware algorithm is much more as compare to proposed algorithm. As existing algorithm violate the SLA and pay penalty for the violation but DVFS do not violate the SLA. So it is better as compared to existing technique.

5.2.5 SCENARIO 5

In the fifth scenario, the no. of host and no. of VMs are 20, Simulation limit is 24*60*1 and find out the variation in power consumption in existing, Proposed and non power aware algorithm and also figure out the performance of DVFS mechanism.

Table 5.8: Comparison with existing technique as per scenario 5

Algorithm	SLA	Energy Consumption	No of VM migration
Non Power Aware	0.000	0.84	0
Existing	0.05127	0.65	64
Proposed	0.000	0.64	0

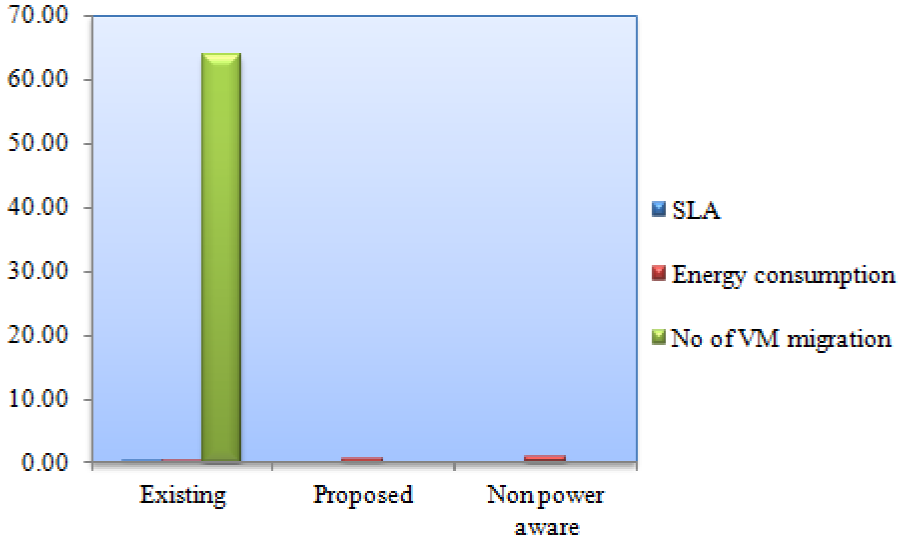


Figure 5.5: Comparison with existing technique as per Scenario 5

On the basis of results, as the number of VM and hosts increases the existing algorithm degrade the energy and also violate the SLA but proposed DVFS consumes less power and do not violate the SLA.

On summarization, it is seen that in every scenario energy consumption is less in the proposed algorithm as compared to existing and non power aware techniques. Proposed technique is better as it do not violate the SLA whereas in existing technique, it also violates the SLA and pay penalty to user. Ultimately, Dynamic Voltage and Frequency Scaling (DVFS) can dynamically adjust the frequency and voltage of host's CPU on the basis of load.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

In the proposed research, researcher extend this technique using dynamic voltage fluctuation system (DVFS). The objective of using DVFS is that, if further migration is not possible or the number of task running on the machine is going to complete, then migration can further reduce the performance. By using DVFS, the voltage given to under loaded machines is reduced which further optimize the energy consumption to next level. Dynamic Voltage and Frequency Scaling (DVFS) can dynamically adjust the frequency and voltage of host's CPU on the basis of load. On conclusion, DVFS has improved the energy consumption without violating the SLA as compare to existing technique.

6.2 FUTURE SCOPE

In proposed work, researchers are conserving the less energy using DVFS. The objective of using DVFS is that, if further migration is not possible or the number of task running on the machine is going to complete, then migration can further reduce the performance. But in existing technique VM migration concept is used that consumes more energy and it also violates the SLA. In future, research can be taken to extend this technique by combining dynamic voltage fluctuation system (DVFS) with VM migration to conserve the energy upto the next level, which will be more efficient.

REFERENCES

[1] Voorsluys, William, James Broberg, and RajkumarBuyya. "Introduction to cloud computing." *Cloud computing: Principles and paradigms* (2011): 1-44.

[2] Azeez, Afkham, SrinathPerera, DimuthuGamage, Ruwan Linton, PrabathSiriwardana, DimuthuLeelaratne, SanjivaWeerawarana, and Paul Fremantle. "Multi-tenant SOA middleware for cloud computing." In *2010 IEEE 3rd International Conference on Cloud Computing*, pp. 458-465.IEEE, 2010.

[3] Wyld, David C. *Moving to the cloud: "An introduction to cloud computing in government"*. IBM Center for the Business of Government, 2009.

[4] Tsai, Wei-Tek, Xin Sun, and JanakaBalasooriya. "Service-oriented cloud computing architecture." In *Information Technology: New Generations (ITNG), 2010 Seventh International Conference on*, pp. 684-689. IEEE, 2010.

[5] Dinh, Hoang T., Chonho Lee, DusitNiyato, and Ping Wang. "A survey of mobile cloud computing: architecture, applications, and approaches."*Wireless communications and mobile computing* 13, no. 18 (2013): 1587-1611.

[6] Mell, Peter, and Tim Grance. "The NIST definition of cloud computing". (2011).

[7] Zhang, Qi, Lu Cheng, and RaoufBoutaba. "Cloud computing: state-of-the-art and research challenges." *Journal of internet services and applications* 1, no. 1 (2010): 7-18.

[8] Lin, Cui, Shiyong Lu, Zhaoqiang Lai, ArtemChebotko, XuboFei, Jing Hua, and FarshadFotouhi. "Service-oriented architecture for VIEW: a visual scientific workflow management system." In *Services Computing, 2008.SCC'08. IEEE International Conference on*, vol. 1, pp. 335-342. IEEE, 2008.

[9] Yu, Jia, and RajkumarBuyya. "A taxonomy of scientific workflow systems for grid computing." *ACM Sigmod Record* 34, no. 3 (2005): 44-49.

[10] Yassa S, Chelouah R, Kadima H, Granado B. Multi-objective approach for energy-aware workflow scheduling in cloud computing environments. The Scientific World Journal. 2013 Nov 4;2013.

[11] Chandrashekar DP. *Robust and Fault-Tolerant Scheduling for Scientific Workflows in Cloud Computing Environments* (Doctoral dissertation, Ph. D. dissertation) The University of Melbourne).

[12] Aksanli B, Venkatesh J, Rosing TŠ. "Using datacenter simulation to evaluate green energy integration". *Computer.* 2012 Sep;45(9):56-64.

[13] Kocaoglu M, Malak D, Akan OB. "Fundamentals of green communications and computing: modeling and simulation". *Computer.* 2012 Sep;45(9):40-6.

[14] Shi Z, Dongarra JJ. "Scheduling workflow applications on processors with different capabilities". *Future generation computer systems.* 2006 May 31;22(6):665-75.

[15] Watanabe EN, Campos PP, Braghetto KR, Batista DM. "Energy saving algorithms for workflow scheduling in cloud computing". *InComputer Networks and Distributed Systems (SBRC),* 2014 Brazilian Symposium on 2014 May 5 (pp. 9-16). IEEE.

[16] Kolpe T, Zhai A, Sapatnekar SS. "Enabling improved power management in multicore processors through clustered DVFS*". InDesign, Automation & Test in Europe Conference & Exhibition (DATE)*, 2011 2011 Mar 14 (pp. 1-6). IEEE.

[17] Pietri I, Juve G, Deelman E, Sakellariou R. "A performance model to estimate execution time of scientific workflows on the cloud". *InProceedings of the 9th Workshop on Workflows in Support of Large-Scale Science* 2014 Nov 16 (pp. 11-19). IEEE Press.

[18] Mao M, Humphrey M. "Scaling and scheduling to maximize application performance within budget constraints in cloud workflows". *InParallel & Distributed Processing (IPDPS), 2013 IEEE 27th International Symposium* on 2013 May 20 (pp. 67-78). IEEE.

[19] Alkhanak EN, Lee SP, Rezaei R, Parizi RM. “Cost optimization approaches for scientific workflow scheduling in cloud and grid computing: A review, classifications, and open issues”. *Journal of Systems and Software*. 2016 Mar 31;113:1-26.

[20] Calheiros RN, Ranjan R, Beloglazov A, De Rose CA, Buyya R. “CloudSim: a toolkit for modeling and simulation of cloud computing environments and evaluation of resource provisioning algorithms”. *Software: Practice and experience.* 2011 Jan 1;41(1):23-50.

[21] Da Costa G, Hlavacs H, Hummel KA, Pierson JM. “Modeling the energy consumption of distributed applications”.

[22] Shojafar M, Canali C, Lancellotti R, Abolfazli S. “An energy-aware scheduling algorithm in DVFS-enabled networked data centers”. *Proc. CLOSER.* 2016 Apr 24:387-97.

[23] Fu J, Moran B, Guo J, Wong EW, Zukerman M. “Asymptotically Optimal Job Assignment for Energy-Efficient Processor-Sharing Server Farms”. *IEEE Journal on Selected Areas in Communications.* 2016 Dec;34(12):4008-23.

[25] Chen W, Deelman E. “Workflowsim: A toolkit for simulating scientific workflows in distributed environments”. *InE-science (e-science), 2012 IEEE 8th International Conference* on 2012 Oct 8 (pp. 1-8). IEEE.

[27] Lee YC, Zomaya AY. “Energy efficient utilization of resources in cloud computing systems”. *The Journal of Supercomputing*. 2012 May 1;60(2):268-80.

[28] Berl A, Gelenbe E, Di Girolamo M, Giuliani G, De Meer H, Dang MQ, Pentikousis K. “Energy-efficient cloud computing”. *The computer journal.* 2010 Sep 1;53(7):1045-51.

[29] Guo L, Zhao S, Shen S, Jiang C. “Task scheduling optimization in cloud computing based on heuristic algorithm”. *JNW.* 2012 Mar 3;7(3):547-53.

[30] Xu, Meng, Lizhen Cui, Haiyang Wang, and Yanbing Bi. "A multiple QoS constrained scheduling strategy of multiple workflows for cloud computing." In *2009 IEEE International Symposium on Parallel and Distributed Processing with Applications*, pp. 629-634.IEEE, 2009.

[31] Pandey, Suraj, Linlin Wu, SiddeswaraMayura Guru, and RajkumarBuyya. "A particle swarm optimization-based heuristic for scheduling workflow applications in cloud computing environments." In *2010 24th IEEE international conference on advanced information networking and applications*, pp. 400-407.IEEE, 2010.

[32] Mezmaz, Mohand, NouredineMelab, YacineKessaci, Young Choon Lee, E-G. Talbi, Albert Y. Zomaya, and Daniel Tuyttens."A parallel bi-objective hybrid metaheuristic for energy-aware scheduling for cloud computing systems." *Journal of Parallel and Distributed Computing* 71, no. 11 (2011): 1497-1508.

[33] Rizvandi NB, Taheri J, Zomaya AY. "Some observations on optimal frequency selection in DVFS-based energy consumption minimization". *Journal of Parallel and Distributed Computing*. 2011 Aug 31;71(8):1154-64.

[34] de Oliveira, Daniel, Kary ACS Ocaña, Fernanda Baião, and Marta Mattoso."A provenance-based adaptive scheduling heuristic for parallel scientific workflows in clouds." *Journal of Grid Computing* 10, no. 3 (2012): 521-552.

[35] Xiao Z, Chen Q, Luo H. Automatic scaling of internet applications for cloud computing services. IEEE Transactions on Computers. 2012 May;63(5):1111-23.

[36] Wright P, Sun YL, Harmer T, Keenan A, Stewart A, Perrott R. "A constraints-based resource discovery model for multi-provider cloud environments". *Journal of Cloud Computing*. 2012 Dec 1;1(1):1-4.

[37] Abrishami, Saeid, Mahmoud Naghibzadeh, and Dick HJ Epema. "Deadline-constrained workflow scheduling algorithms for Infrastructure as a Service Clouds." *Future Generation Computer Systems* 29, no. 1 (2013): 158-169.

[38] Guérout T, Monteil T, Da Costa G, Calheiros RN, Buyya R, Alexandru M. "Energy-aware simulation with DVFS". *Simulation Modelling Practice and Theory*. 2013 Dec 31;39:76-91.

[39] Zhang, Fan, Junwei Cao, Keqin Li, Samee U. Khan, and Kai Hwang. "Multi-objective scheduling of many tasks in cloud platforms." *Future Generation Computer Systems* 37 (2014): 309-320.

[40] Poola D, Garg SK, Buyya R, Yang Y, Ramamohanarao K. “Robust scheduling of scientific workflows with deadline and budget constraints in clouds”. InAdvanced Information Networking and Applications (AINA), 2014 *IEEE 28th International Conference* on 2014 May 13 (pp. 858-865). IEEE.

[41] J.-H. Chen, F. Abedin, K.-M. Chao, N. Godwin, Y. Li, C.-F. Tsai, “A hybrid model for cloud providers and consumers to agree on QoS of cloud services”, Future Generation Computer Systems (2014).

[42] P. Korambath, J. Wang, A. Kumar, L. Hochstein, B. Schott, R. Graybill, M. Baldea, J. Davis. "Deploying Kepler Workflows as Services on a Cloud Infrastructure for Smart Manufacturing", *Accepted by the Second International Workshop on Advances in the Kepler Scientific Workflow System and Its Applications, at International Conference on Computational Science*

[43] Wu CQ, Lin X, Yu D, Xu W, Li L. “End-to-end delay minimization for scientific workflows in clouds under budget constraint”. *Cloud Computing, IEEE Transactions* on. 2015 Apr 1;3(2):169-81.

[44] Malawski, Maciej, KamilFigiela, Marian Bubak, EwaDeelman, and JarekNabrzyski. "Scheduling multilevel deadline-constrained scientific workflows on clouds based on cost optimization." *Scientific Programming* 2015 (2015): 5.

[45] Zhao Y, Li Y, Raicu I, Lu S, Lin C, Zhang Y, Tian W, Xue R. “A Service Framework for Scientific Workflow Management in the Cloud”. *Services Computing, IEEE Transactions* on. 2015 Nov 1;8(6):930-44.

[46] Zhou AC, He B, Cheng X, Lau CT. “A declarative optimization engine for resource provisioning of scientific workflows in iaas clouds”. *InProceedings of the 24th International Symposium on High-Performance Parallel and Distributed Computing* 2015 Jun 15 (pp. 223-234). ACM.

[47] ul Islam FM, Lin M. “Hybrid DVFS scheduling for real-time systems based on reinforcement learning”. *IEEE Systems Journal.* 2015 Jul 21.

[48] Chen W, Ferreira da Silva R, Deelman E, Fahringer T. "Dynamic and Fault-Tolerant Clustering for Scientific Workflows".

[49] Tang Z, Qi L, Cheng Z, Li K, Khan SU, Li K. " energy-efficient task scheduling algorithm in DVFS-enabled cloud environment". *Journal of Grid Computing*. 2016 Mar 1;14(1):55-74.

[50] Li X, Song J, Huang B. "A scientific workflow management system architecture and its scheduling based on cloud service platform for manufacturing big data analytics". *The International Journal of Advanced Manufacturing Technology*. 2015:1-3.

[51] Ding J, Zhang Z, Ma RT, Yang Y. "Auction-based cloud service differentiation with service level objectives". *Computer Networks*. 2016 Jan 15;94:231-49.

[52] Cotes-Ruiz IT, Prado RP, García-Galán S, Muñoz-Expósito JE, Ruiz-Reyes N. "Dynamic Voltage Frequency Scaling Simulator for Real Workflows Energy-Aware Management in Green Cloud Computing". *PloS one*. 2017 Jan 13;12(1):e0169803.

[53] Zhao, Qing, CongcongXiong, Ce Yu, Chuanlei Zhang, and Xi Zhao. "A new energy-aware task scheduling method for data-intensive applications in the cloud." *Journal of Network and Computer Applications 59* (2016): 14-27.