International Journal of Engineering & Technology, 7 (4.31) (2018) 516-520

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Analysis of DVFS Technique for Efficient - Energy Management in Cloud Data Center

Joshua Samual, Masnida Hussin

Faculty of Computer Science and Information Technology, University Putra Malaysia (UPM),
43400 UPM Serdang Selangor Darul Ehsan
**Corresponding author email: masnida@upm.edu.my*

Abstract

Cloud data center contains various resources which are utilized continuously without any break. The data center consumed large energy to keep the components to run 24/7 for achieving certain performances. Such energy usage becomes one of the major issues in the Cloud data center. It is due to the Cloud availability is highly demanded in network community. In this study, we formed an analysis on the energy consumption by considering the CPU usages through the existing Dynamic Voltage and Frequency Scaling (DVFS) techniques that proposed in existing researches. The aim of this work is to investigate and identify Cloud services application factors that can be employed on the DVFS for better energy management in Cloud data center. Our study expresses the areas of the Cloud service applications such as Business Application-as-a-Services, Consumer Application-as-a-Services and Scientific Application as-a Service that embedded in DVFS where it can be part of the energy saving contributors. We also analysed the two main factors in DVFS are proportional to time and frequency that can be adjusted towards energy efficient in the data center. The survey is also investigated on how far such functions can be manipulated for energy saving while investigating potential solutions for further enhancement.

Keywords: *cloud data centre, energy efficiency, DVFS, cloud applications.*

1. Introduction

In this present era, Cloud computing proved to be a promising technology to the world-wide users which deliver computing services over the Internet. It is one of the fastest growing computing technology and the use of Cloud computing become the 5th utility of the daily need beside water, electricity, gas and telephone [1]. Cloud computing provides a cost effective, elastic scaling-up and scaling down provision which attract large and small scale industries towards it. About 70% of the companies from all over the world have showed their interest by adopting this technology and 30% of the companies have the intention to deploy it in near future. In addition, due to those features the new information technologies such as Big Data, Internet of Things, and Artificial Intelligent automation are deployed in the Cloud. The industries are heavily relay upon the Cloud computing to process their data as quick as possible [2-3]. With the increase in the demand of the users it become necessary for the Cloud service provider such as Amazon, IBM, MICROSOFT, Google, Facebook etc. to deploy large number of data centers all over the world to support computing demands from their users [4-5].

The main responsibility of Cloud data center is to receive the task from the end users and process those by assigning it to the proper virtual server. Figure 1 shows the architecture diagram of the Cloud data center [5]. Basically, the bottom layer of this diagram repre-sents the various resources that the Cloud data center contains such as Network API, Hypervisor API, Storage API, and Security API. The end users at the top layer send their request to the re-spective Cloud data center through the API. Cloud allocates the task to the respective virtual machine which processes the task efficiently. The allocation of the task is done through various allocation techniques. Mostly Cloud data center contains number of virtual servers and these virtual servers are created from a physical machine. This process is called as Virtualization. Figure 2 shows the architecture diagram of the virtualization technique and how it been created [5].

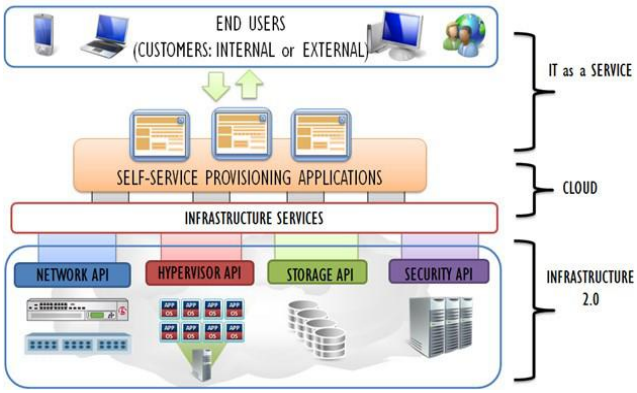

Fig 1: Architecture diagram of the Cloud data center [5]

Copyright © 2018 Authors. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

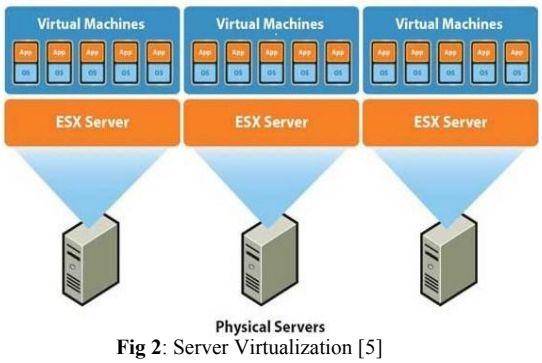

Fig 2: Server Virtualization [5]

The above figure shows that several Virtual Servers were created from the Physical Server. The architecture diagram is divided into three layers such as physical layer which contains physical machine and its resources such as CPU, RAM and Storage. In Virtualization layer the process of virtualization take place. The Virtualization of the Server is done through some Virtualization software such as VMWare EXSI, VSphere, Oracle Virtual Box, and Hyper-V. All the Virtual Servers are created from the physical server using any one of the mentioned Virtualization techniques. In Virtual Server layer the Virtual machines are deployed and executed. Upon these Virtual Servers the operating systems were installed, and the applications are run upon this operating system. One of the major challenges which are faced by the Cloud data center is high amount of energy consumption. According to [5] the IT infrastructure which contains thousands of servers and other IT equipment are the main contributor to the energy consumption in a data center and up to 60% of the overall data center power consumption is mainly dominated by the enterprise servers. One of the studies reveals that in 2012 there is 15% of the energy consumed by the European data centers and it is expected that it will increase up to 5 to 10% in 2017 [6]. Further it says that by 2020 around 93 TWh of energy will be consumed. It is necessary that the servers should be available and accessible throughout the year for 24/7 and 365 days basis to gain good service reputation. This process will not only lead to the financial loss, but it will cause the emission of carbon foot print in the atmosphere.

Fig 3 shows the predictive analysis between 2007 and 2020 for the worldwide carbon emission from the data centers. From the fig it is analyzed that in the year 2007 around 80 metric megaton of CO_2 is emitted in the atmosphere and by looking unto the accelerate growth in energy consumption by the Cloud data center it is predicate that by the year 2020 about 340 metric megatons of CO_2 will be emitted in the atmosphere which will cause harm to all the living things [7].

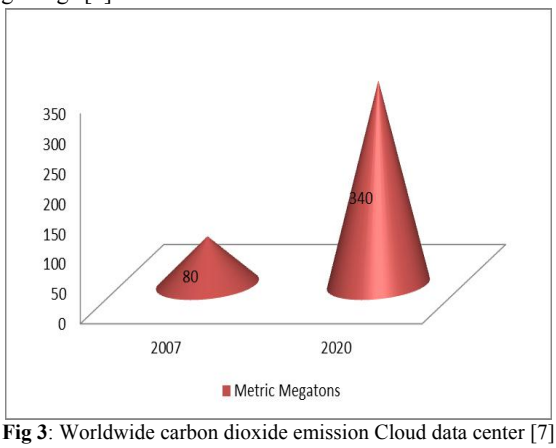

Fig 3: Worldwide carbon dioxide emission Cloud data center [7]

The objectives of this study are to investigate the existing DVFS technique towards energy efficiency and to analyze the system and application factors which contribute more towards energy consumption in a Cloud data center.

The rest of the work in this paper is divided into 4 parts. The analysis of Cloud service applications that consumed energy is presented in section 2. In section 3 we reviewed DVFS factors that contribute the energy efficient. Finally, the paper is concluded in section 4.

2. Cloud Service Applications Versus Energy Consumption

Cloud data center are the collection of physical and virtualized server which runs 24 hours throughout the year in order to provide the services to the users. The energy consumption in the Cloud data center mainly depends upon two main factors such as:

2.1. The Resource Management Which is deployed on the Infrastructure

Cloud data center contains various types of resources such as server, memory, storage, network devices, and cooling systems. The main responsibilities of the resource management are to select the required resources and provision it to the single or a set of requests which are received by the Cloud data center to meet the performance objective of the users [8]. In Cloud computing environment these resources are deployed in four types of deployment infrastructure such as Public Cloud, Private Cloud, Hybrid Cloud and Community Cloud. In this entire deployment infrastructure, the resource management plays a very important role.

The studies in [5, 8] states that most of the energy in a Cloud data center is consumed by the IT infrastructure which consist of servers and another IT equipment's. About 60% of the overall energy consumption in a data center is dominated by the power consumption of the enterprise server. Fig 4 shows the percentage breaks down of various parts in a Cloud data center which consume energy [8]. It shows that server consumes 56% of the total energy followed by cooling systems which consumes 30% of the total energy, power equipment consumes 8%, network devices consumes 4% and lighting equipment's 2%. From the above analysis it is understood that in a Cloud data center among the other entire resource's server consumes more energy. In a server the maximum energy is consumed by the CPU. About 30% of the energy in CPU is consumed during the ideal hour and about 70% of the energy is consumed during the peak hour. Besides CPU the memory used in the server such as dynamic random-access memory (DRAM) also consumes 50% of the total energy and 25% of energy is consumed by secondary memory such as disk.

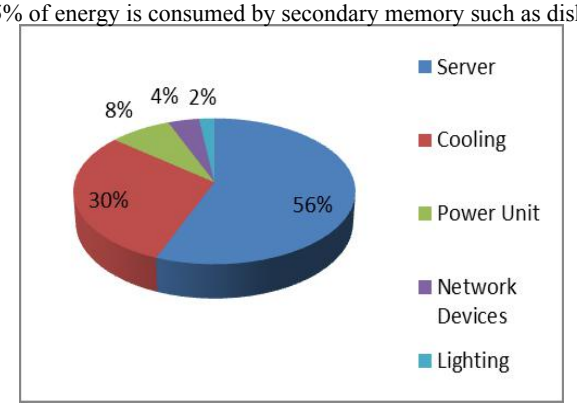

Fig 4: Cloud Data Center Energy Break Down [5]

In most of the proposed work it is noted that the energy consumed by the CPU is taken into consideration and lot of improvement is been done to optimize the energy consumed by the CPU but other area such as energy consumed by DRAM, disk, network devices are not taken much into account while considering about energy optimization.

2.2. The Efficiency of an Application which is running on a System

Cloud computing offers various types of services such as Infrastructure-as-a-service (IaaS), Platform-as-a-Service (PaaS), and Software-as-a-Service (SaaS) in which SaaS is a type of service were the service providers host various application on the Cloud and make them available to their users at any time over the internet on pay-for-use-bases based on SLA [3, 7]. In most of the past research only CPU in the server is taken into consideration for optimizing the energy consumption. But the energy consumption in Cloud data center is not only contributed by the resources but the efficiency of the application should also be considered.

One of the major factors which affect the efficiency of the application in energy consumption is the type of the application run-ning on the Cloud. Specifically, SaaS provides various types of application to the users. Each and every application running on the Cloud are not same. They vary based upon different parameters and the energy consumption of each and every application is also different. So, in order to estimate the energy consumption of Cloud data center we cannot relay only upon the quantity of energy consumed by resources and we cannot take the optimization result as an accurate result. But to optimize the energy in a Cloud data center and to measure the energy consumption accurately we have to consider both the factor that is the resource management and the application which is running on the system. Under SaaS the type of application which is running on a Cloud are classified into three categories such as.

2.2.1. Consumer Application (Consumer App –as – a – Service)

Consumer applications are those applications which are used by the people in the community for their personal uses. In Cloud, the consumer applications are classified into education, entertainment and gaming applications which are downloaded in mobile devices such as Laptop, Smartphones and Tablets through app stores [9]. For example, Dropbox, iCloud, Share it, Audiobox.fm, Waze and many more similar applications. Cloud provides some free downloadable applications and for some applications users have to pay for it. Once the consumer applications are download-ed in the mobile devices they can be stored in the mobile devices and then they can be accessed by the users anytime they want. One of the greatest advantages of using consumer application is the accessibility. Since these applications can be used in mobile devices the users can access the application any were they want. For an example the user can share any type of file using Dropbox from any were. Beside advantage mobile devices runs on a bat-tery and too long uses of those applications will consumes more energy from the battery and make the performance of the battery weaker. For example, the usage of entertainment applications where longer usage of the applications will be increased heat in the device. This is the greatest challenge faced by the mobile devices when the applications run on it.

2.2.2. Business Application (Business App – as – a- Service)

Business applications are those applications which are used by all kinds of enterprise for the development of the business. These applications are also called as an enterprise application which helps to increase the product of the business and measure the accuracy of the business function. Cloud provides various types of applications such as Cloud CRM, Amazon web service, Phreebooks, for accounting and Palo BI suits for business intelligence [10].

Basically, all these applications are hosted in a Cloud remote server. For example, an accounting application which provides accounting facilities for the business send data to the Cloud where it is processed and return back to the users. In this all the functions of the business process are performed off side that is on the remote server not on the user's desktop that means no need to buy an accounting application and install it into the desktop like traditional application. These applications can be requested by the Cloud service providers whenever the users wanted to work out with their business accounts and along with application the service provider will allocate the infrastructure such as sever to process the request and storage to store the data. This storage is flexible and the size of the storage can be extended based upon the requirement. All these services are provided by the cloud providers based upon pay-per-as-you-use in context with SLA. The first greatest challenge is the energy consumption. Sometime the organizations may use the application for the longer period of time in a Cloud which will consume more energy and it will also affect the balance sheet of an organization. The second problem is with the security. Since Cloud service is provided by the third party and the enterprise information are stored with them a high level of security is to be provided.

2.2.3. Scientific Application (Scientific App – as – a – Service)

Scientific applications are high performance applications which are used by the scientist for the research purpose such as Big data analytics, IoT application, and Artificial Intelligence simulation tools. Cloud computing provides scientific app–as–a-service which provision scientist with a complex infrastructure, resources, storage and applications dynamically on a pay-per-use-model with in the context of service level agreement (SLA). The scientific applications are very complex applications which consist of many computational steps to generate a large set of result from a large set of data and are very flexible to gather any amount of data and process those data in a short period of time [3][7]. Along with this Cloud provides large amount of storage which allows the researchers to analyze the data and store the data. The Cloud storages are scalable that is in case of large volume of data extra storage space can be requested. The major challenge with in the scientific application hosted in the Cloud is that some of the scientific application are very complex and required to collect the data throughout the day on 24/7 basis which keeps the server busy. This will lead to a high amount of energy consumption which will lead to a greatest impact such as generate huge amount of heat.

Several studies [3, 5, 11] said that Cloud application such as data analytic and Internet of Things that collects and analyze large amount of data from sensor, scientific application, simulations and social network analysis have a massive impact on the global amount of energy being consumed in data center. another study revealed that to process the Big data application such as Hadoop needs lot of power and each and every unit of energy which is consumed by this application will have a direct impact on the balance sheet of a company and also with the increased power more heat will be generated [8]. The authors in [8] also revealed that the number of connected devices for Internet of Things in a Cloud computing will increase to 6.58 billion in 2020 as compared with the current figure of 6.3 billion globally.

From the above studies it is analyzed that the high amount of energy is consumed by the scientific applications which required complex environment to run. High performances computing with high performance CPU are used to process this application in a Cloud data center. So, it becomes mandatory to propose an advance technique which can consider various metric related to efficient energy management for the applications. The current techniques are only applicable to efficiently manage the energy consumption on the resources. But since the current trend is changed and lot of high-level scientific applications are processed

by Cloud data center it is required that while managing the energy consumption efficiently the energy consumed per application and a technique to efficiently manage the energy consumption by an application is to be consider.

3. Review on DVFS Factors Towards Energy Efficiency

Dynamic Voltage and Frequency Scaling (DVFS) is one of the energy management techniques which is utilized to reduce the energy consumption of CMOS Integrated circuit such as computer processor and circuit bus by reducing the frequency at which it operates [2, 4]. It is one of the predominant techniques which are widely used to manage and control the energy consumption of any computer ranging from mobile phone to large servers in the data center. In DVFS technique, the energy consumption is minimized by adjusting the frequency and the voltage of the processor based upon the work load. Sometime the frequency is adjusted to high and sometime to low level. Basically, the DVFS is activated in four different modes such high frequency, low frequency, available frequency for the CPU and on demand where dynamically choosing the frequency level [5]. Since the voltage frequency and the power consumption are interdependent to each other [5] the DVFS technique can provide significant energy saving profile without any performance loss. It dynamically adjusts the voltage and frequency of the processor during task execution process without to restart the power supply. The energy consumed by DVFS is given by the equation as follows [2].

$$E = C*F*V^2+Pstate. \quad (1)$$

where E refers to energy consumed and measured in joules (j), C is the capacitance of the transistor gates, F is the operating/clock frequency and V denotes voltage supply, respectively. The power consumed by the task may be decreased by reducing V or F. In this equation the voltage that required for execution operation is decided by the frequency at which the circuit is reduced if the frequency becomes lower. Therefore, there are two main important factors in the DVFS technique which needs to be considered for energy efficiency.

3.1. Frequency is Directly Proportional to the Completion Time

According to the DVFS equation, it means that the completion time of a task will increase or decrease with respect to the frequency of the CPU. In the Cloud data centre, the task which is processed by the virtual machines are of different types and sizes. When the frequency of the CPU is adjusted to the maximum the execution of the task will be done fast and the task completion time is minimized. But when the frequency of the CPU is adjusted to minimum than the execution of the task will be slow, and the task completion time is maximized [4]. But in order to improve the Cloud user's satisfaction, in most of the cases the frequency of the CPU is kept to the maximum so that the completion time of the task will be fast while providing quick response. However, when the frequency is set to high the energy consumption explicitly increased where on the other hands the task completion time is minimized.

3.2. Load is Directly Proportional to the Frequency

The frequency of the CPU increases, or decreases is according to the level of the load. As the load increases the frequency of the CPU will also increase. In the Cloud data center, it is very necessary to schedule the load to each virtual machine so that there is no virtual machine is overloaded and under loaded [5, 9]. The frequency of the CPU should be adjusted in such a way that whenever if any type of load is assigned to the virtual machine those loads should be processed as fast as possible. This is because when there are too much of load is accumulated in the virtual machines the CPU needs high frequency to process those loads which will consume high amount of energy. At the same time if the frequency is kept to low than the processing speed less that makes the energy consumption will be less. But in most of the cases the frequency of the CPU is kept to the maximum so that the entire incoming load can be processed in quick for users' satisfaction. At this point only, the quality of service regarding the load balancing is considered but not the energy consumption.

Even though DVFS proved to be one the effective technique to efficiently manage the energy consumption in the Cloud data center it has some weakness such as:

- When the frequency is adjusted to low the processing time will increase which will cause delay in processing and delay in execution.
- When the frequency is adjusted to high the processing time will be fast, but the energy consumption will be high.
- Since the frequency can be adjusted to low and high the performance of the data center gets affected.
- Under DVFS technique the quality of service (QoS) is not been considered equally with energy saving.

In the past research DVFS techniques are used in various ways [2, 5, 9] to scale the CPU frequency and minimize the voltage consumed by the server. According to such DVFS algorithms basically, the optimal frequency CPU is calculated to find out the most suitable server out of the given frequency set. The optimal frequency of the CPU can be identified based upon two factors: (i) the number of instructions in each task which is known and (ii) the deadline for each task which is given by the user. These two factors are divided to get the optimal frequency of the CPU [2]. Based on the factors, if the given optimal frequency of the CPU finds the parameters (i.e., execution times, throughput) which are equal to the given frequency set then the controller will assign the task to the server [9]. But if the performance parameters are do not met the factors than the controller will change the optimal frequency one of the available servers and assign the task to that server. In such algorithm the optimal frequency of the CPU is considered, and the frequency of the CPU is adjusted to the optimal frequency of the CPU [5].

The DVFS technique is only used to adjust the frequency of the CPU in the computational device and manage the energy consumption efficiently due to lot of improvement is achieved in energy consumed by the CPU. The modern CPU is built with dynamic energy consumption technique which manages the energy efficiently in the Cloud data center [13-14]. But these techniques are very rarely used in other resources such as memory, storage, network devices and cooling system which also contributed towards energy saving. We have analyzed and identified several significant DVFS techniques that implemented to minimize the energy consumption for Cloud computing efficiently. The analysis is given in Tables 1.

Table 1: The Analysis of DVFS Techniques in Cloud

Method	Resource Management				Task
	Server CPU	Storage	Cooling System	Network Devices	
DVFS-enabled workflow task scheduling [2]	Yes	Yes	No	Yes	Parallel Task
DVFS with FCFS [4]	Yes	Yes	Yes	Yes	Heterogenous Tasks
DVFS-pref [5]	Yes	Yes	No	Yes	Batch workload

DVFS with Big O's [12]	Yes	Yes	No	Yes	Incoming request
DVFS with Job Scheduler [13]	Yes	Yes	No	Yes	Parallel Task
DVFS with Minimum Energy Consumption Ratio Increment [14]	Yes	Yes	No	Yes	Batch Task

According to the above table it shows that there are many other resources such as storage, cooling system and network devices also consumed energy in the Cloud data center. Since DVFS technique proved to be an effective technique in terms of efficient energy management it can also be used in other resources other than CPU for better energy management. Due to the DVFS technique able to adjust the frequency and voltage levels, it can be enhanced to dynamically monitor other devices in the data center. Moreover, the table also shows that the frequency of the CPU is adjusted based upon a particular type of task at a time such as batch task or parallel task etc. According to the authors in [4] the energy management should be considered on scheduling of hybrid task dynamically. The frequency of the CPU should adjust according to the requirement of the hybrid task. Beside the DVFS technique, the method of task scheduling also contributes on the energy saving while improving the Cloud performance that leads to better QoS.

4. Conclusion

In this paper we have reviewed about the DVFS techniques which are used in the Cloud data center to manage the energy efficiently. Energy efficient is one of the challenging researches in the Cloud data center. Many techniques and policies are implemented to minimize the energy and to improve the efficiency of the Cloud data center. From our review it is clear that there is still more improvement needed to make in order to utilize the DVFS func-tions for better energy saving. The effective energy management can help to reduce the total cost of ownership of the Cloud providers and make sustainable environment. We have identified the energy consumption factors in regards Cloud applications which are can be monitored and solved using the DVFS technique. The multi-consideration among the Cloud applications, DVFS factor and energy consumption towards effective energy management optimistically brings green distributed computing.

Acknowledgement

This work is supported by a Research Management Center (RMC) University Putra Malaysia under Putra Grant 9595900.

References

[1] Shikha Gupta, Suman Sanghwan,(2015), Load Balancing in cloud computing, International Journal of Science, Engineering and Technology Research (IJSETR), Vol 4, Issues 6, ISSN: 2278-7798.

[2] Zhuo Tang, Ling Qi, Zhenzhen Cheng, Kenli Li, Samee U, Khan, Keqin Li, (2015), An Energy-Efficient Task Scheduling Algorithm in DVFS- Enabled Cloud Environment, J Grid Computing, Springer, DOI 10.1007.

[3] Hussin, Masnida; Muhammed, Abdullah; Mahmood, Y. M. Raja Azlina Raja (2017), An Adaptive Energy Allocation for High-Performance Computing Systems Using a Cyber-Physical Approach, Advanced Science Letters, vol. 23, no. 6, pp. 5045-5049(5).

[4] Sakshi Grover, Mr. Navtej Singh Ghumman, (2016), Power Saving Load Balancing Strategy Using DVFS in Cloud Computing Environment, International Journal of Computer & Technology, Vol 15, Number 13, pp- 7333, ISSN 2277-3061.

[5] Patricia Arroba, Jose M. Moya, Jose L. Ayala, Rajkumar Buyya, (2016), Dynamic Voltage and Frequency Scaling -Aware Dynamic Consolidation of Virtual Machine for Energy Efficient Cloud Data Centers, Concurrency Computation Practice and Experience, Wiley, DOI 10.1002.

[6] Manuel Combarro, Andrei Tchernykh, Alexander Drozdov, Dzmitry Kliazovich, Gleb Radchenko, (2016), Energy-Aware Schedduling with Computing and Data Consolidation Balance in 3- Tier Data Center, International Conference on Engineering and Telecommuni-cation, IEEE, DOI 10.1109.

[7] Atefeh Khosravi, Rajkumar Buyya, (2017), Energy and Carbon Footprint- Aware Management of Geo-Distributed Cloud computing Data Centers: A Taxonomy, State of the Art, and Future Directions, IGI Global, DOI: 10.4018/978-1-5225-2013-9.ch002.

[8] H. Rong, H. Zhang, S. Xiao, C. Li, and C. Hu, (2016), Optimizing energy consumption for data centers Renewable and Sustainable En-ergy Reviews, Elsevier, Volume 58, , Pages 674-691.

[9] Vrunda J.Patel , Hitesh A. Bheda,(2014), An advanced Survey On The Research Issues Of Energy Management In Cloud Computing, International Journal of Advanced Research in Computer Science and Software Engineering, Vol 4, Issue 1, ISSN: 2277-128X, PP163-166.

[10] G. Kiryakova, N. Angelova, L. Yordanova,(2015), Application Of Cloudcomputing Services In Business, Trakia Journal of Sciences, Vol. 13, Suppl. 1, pp 392-396, ISSN:1313-3551(online), doi:10.15547/tjs.2015.s.01.067.

[11] Christian Vecchiola, Suraj Pandey, Rajkumar Buyya, (2010), High-Performance Cloud Computing: A View of Scientific Applications. IEEE Xplore, Electronic,ISSN: 2375-527X, DOI: 10.1109/I-SPAN.2009.150.

[12] A.Paulin Florence, V.Shanthi, C.B. Sunil Simon, (2016), Energy Conservation Using Dynamic Voltage Frequency Scaling for Computational Cloud, The Science World Journal, Hindawi Publishing Corporation, Vol 2016, Article ID 9328070, DOI 10.1155/2016/9328070.

[13] Chia-Ming Wu, Ruay-Shiung Chang, Hsin-Yu Chan, (2014), A green energy- efficient scheduling algorithm using the DVFS tchnique for cloud data centers, Future Generation Computer Systems, Elsevier, PP: 141-147.

[14] Songyun Wang, Zhuzhong Qian, Jiabin Yuan and Ilsun You,(2017), A DVFS Based Energy-Efficient Task Scheduling In a Data Center, Special Selection on Emerging Trends, Issues, And Challenges In Energy-Efficient Cloud Computing, IEEE Access, Vol 5, ISSN: 2169-3536, DOI: 10.1109/ACCESS.2017.2724598, PP-13090-13102.