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A Study on Energy Efficient Resource Scheduling Algorithms in Cloud Computing

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Abstract: **Cloud computing is a rapidly growing IT infrastructure which provides various cost-effective computing services with highly scalable computing resources through internet on demand. The quality of services (QoS) has been improved with the advancements in cloud services. These advancements lead to the increase in the demand of cloud computing resources. One of the principle challenges in cloud computing is to increase the availability of computational resources, while maintaining energy efficiency and reducing operational expenses.In energy efficient cloud computing, it is important to effectively utilize the energy for computing resources to attain environmental sustainability since its generation relies upon natural dynamic conditions. An efficient task scheduling and resource allocation scheme guarantee energy efficiency to the cloud clients on-demand in pay-as-you-use model. In this paper, we have presented views on various allocation policies found in the research history and analysed different energy efficient resource scheduling algorithms in cloud computing.**

Keywords: **Cloud Computing, Energy Efficiency, Task Scheduling, Resource Scheduling, Cost effective.**

I. INTRODUCTION TO CLOUD COMPUTING

Cloud computing is a cost effective and rapidly growing computing technology that extends utility-based services and dynamic provisioning to a large number of users [1]. The idea of dynamic provisioning in cloud computing is connected to services, processing capability, systems administration, networking, storage services and IT infrastructure to meet client requirements. The resources are made accessible for the clients through the Internet and offered on a pay-as-use basis from various Cloud service providers [2].

The cloud computing is a new paradigm for enterprises, that can successfully encourage the execution of tasks. Task scheduling is a critical issue which is extraordinarily affecting the execution of cloud computing environment. The cloud service providers and consumers have distinctive objectives and requirements [3].

II. ENERGY EFFICIENT RESOURCE SCHEDULING IN CLOUD COMPUTING

Cloud infrastructures are designed to help the accessibility and deployment of various service-oriented applications by the clients. The rapid growth in cloud services increased the number of physical devices for provisioning of cloud-based applications and services which resulted in the exponential growth of power consumption. It is assessed that, by 2020, there will be more than 50 billion computing devices associated with the Internet all anticipated to leverage the availability of different cloud services and applications [4].

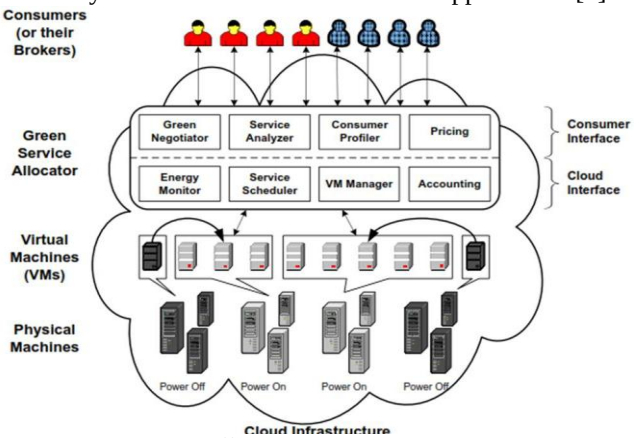

Fig. 1 Energy Efficient Cloud Computing Architecture

The innovations in cloud services challenging the cloud service delivery model in capacity and availability to interconnect the cloud to client's locations with ensured Quality of Service (QoS). Cloud services are made accessible through the server firms or datacenter. For the increasing demand for computations and processing huge data, the cloud environment provides high performance servers and highly scalable fast mass storage devices. These computing resources are the vital origin of the energy consumption in datacenter along with cooling equipment. One of the key challenges is to reduce Energy Consumption by resources to maintain environment sustainability.

The economic, environmental and societal effect, significant academic research and industrial research effort has been focused recently on reducing the energy consumption in cloud computing [5]. Because of high energy utilization by the datacenter, it is required to develop a cost-effective energy efficient innovation to design energy efficient datacenter. Here, the cloud datacenter can decrease overall power consumption through server consolidation and task consolidation using the virtualization by sharing tasks by similar server and unused servers can be turned off.

III. RELATED WORK

Energy efficiency is progressively significant for cloud computing, because of the expansion in the utilization of cloud services, along with increase in energy costs. There is a

need to decrease energy consumption and power dissipation which require the optimal energy efficient technology that reduces total energy utilization of computation, storage services and network communications. Energy efficiency in cloud computing is a powerful operational strategy which can benefit both service providers and service consumers. The ongoing research trends about energy efficient resource allocation have distinguished some of the following key area for energy-saving strategies in cloud computing infrastructure:

- *Importance of Hardware cooling requirements:* Cloud service providers are responsible for selecting hardware devices by studying the electricity benchmarks needed to run the IT load and the consumption figures for identifying the energy required to keep those hardware devices cool such as storage, servers and network devices.
- *Disciplined storage architecture:* Well Organized storage-tiering strategy helps indata management processes are effective in reducing energy consumption for cloud providers.
- *Virtualization:* cloud service providers can manage certain instances of running applications by using virtualization which enables service providers to keep certain servers at a higher capacity of utilization and avoid from turning on others until the point that they are required to handle the load, thereby improvising resource utilization and in turn enhancing cloud computing energy efficiency.
- *Coordinating infrastructure investments closely for the requirements of actual application:* Cloud service providers need to examine the applications that their clients intend to run, and also manage where those applications run [6].
- *Dynamic voltage and frequency scaling (DVFS):* The DVFS method is utilized to decrease the power dissipation created by the chip in two diverse ways. The energy saving can be achievable by balancing naturally the working frequency of the processor with the assistance of system clock available on board which decreases the heat created by the chip on processing [7].
- *Task Consolidation:* In paper [8], Srikantaiah et al. have discussed about an approach to turn off the idle machine by finding the minimum number of suitable machines to which the task to be allocated.
- *Resource Scaling:* The minimum number of resources are allotted to the set of tasks to meet the deadline so that the task will be completed before the deadline to minimize the energy consumption.
- *Powering down:* Turning off the whole framework when not being used or in idle state can be viewed as a key zone of Energy Aware Computing.

IV. DIFFERENT ENERGY EFFICIENT SCHEDULING ALGORITHMS IN CLOUD

Energy-Efficient Resource Allocation and Provisioning Framework for Cloud Datacenter

In this Paper, Firstly, they proposed framework contains the prediction of number of virtual machine (VM) requests arriving at cloud datacenter in the near future, along with the requirement of CPU and memory resources related with each of these requests. Secondly, itprovides precise estimations of the number of physical machines (PMs) that cloud datacenter require to serve their users, and Lastly, reduces power consumption of cloud datacenter by putting nonessential PMs to sleep.The combination of machine learning clustering and stochastic theory is used to develop a prediction approach which predicts both the number of VM requests and the amount of cloud resources related with each request and proposed adaptive improvements to their predictor that make the prediction parameters tuneable in real time based on the actual request load. This expands the prediction exactness after some time and keeps away from the requirement for frequent model training that other machine learning approaches, for example, Neural Network, suffer from. They proposed a coordinated resource provisioning system depends on the proposed prediction ways to make suitable energy-aware resource management choices. They utilized genuine Google data traces to assess the effectiveness of their framework [9].

Energy-efficient Scheduling Policy for Collaborative Execution in Mobile Cloud Computing

In this paper, they have explored the scheduling policy for collaborative execution in mobile cloud computing. A mobile application is represented by an order of fine-grained tasks defining a sequential topology, and each of them is executed either on the mobile phone or offloaded onto the cloud side for execution. The main design objective is to reduce the energy consumption by the mobile phone, while meeting a period of deadline. Here, they have formulated minimum energy task scheduling issue as a constrained shortest path problem on a directed acyclic graph, also, adapt the standardized "LARAC" algorithm to solve this issue roughly. Numerical simulation proposes that a one-climb offloading approach is energy efficient for the Markovian stochastic channel, in which at most one migration from mobile devices to the cloud is occurred for the collaborated task execution. Also, compared with independent mobile execution and cloud execution, the ideal collaborative execution methodology can essentially save the energy consumption on the mobile deice [10].

Task Scheduling and Server Provisioning for Energy-Efficient Cloud-Computing Data Centers

In this paper, they have provided an optimization model approach to reduce energy consumption in cloud data centers. In this approach, they have considered an issue of integer programming problem to reduce energy consumption in the cloud data centers by scheduling tasks to least number of servers while keeping the response time constraints for task. They have proved that the average response time of task and the number of active servers expected to meet certain time constraints are bounded using a greedy task scheduling policy. Furthermore, they proposed the most-effective server-first task-scheduling policy to reduce energy disbursement as a practical scheduling policy. The proposed scheduling scheme for data center are simulated with heterogeneous tasks. The simulation results demonstrate that the proposed task

scheduling policy minimizes energy consumption by server energy utilization on average over 70 times when contrasted with the energy utilized under not-optimized random-based task-scheduling policy. They showed that energy savings are achieved by reducing the number of servers allocated [11].

Dynamic Heterogeneity-Aware Resource Provisioning in the Cloud

In this paper, they furnish Harmony, a Heterogeneity-Aware dynamic capacity provisioning policy for cloud data centers to address the failure to consider the heterogeneity of both machines and workloads which lead to both sub-optimal energy savings and extensive delays in scheduling, because of incompatibility between workload requirements and the resources offered by the provisioned machines. In particular, they have first utilized the K-means clustering algorithm to divide workload into well-defined task classes with homogeneous characteristics in terms of resource and performance requirements. Then they presented an approach that dynamically balancing the number of machines to reduce energy utilization and delay in scheduling. Simulations using traces from a Google's compute cluster reveal Harmony can minimize energy utilization by 28 percent compared to heterogeneity-oblivious solutions [12].

Dynamic Energy-Aware Capacity Provisioning for Cloud Computing Environments

In this paper, they have used real workload traces from Google's compute cluster for broad investigation and simulation to demonstrate their proposed framework which can achieve significant decrease in energy cost, while maintaining an acceptable average scheduling delay for individual tasks. They have provided a control-theoretic solution for the dynamic capacity provisioning issue that reduces the total energy cost while meeting the performance objective as far as task scheduling delay. In particular, they have demonstrated this problem as an obliged discrete-time optimal control problem, and utilize Model Predictive Control (MPC) to locate the optimal control approach. They have designed a dynamic capacity provisioning framework to control the number of active servers in the data center as indicated by demand fluctuation, inconsistency in energy costs and the cost of dynamic capacity reconfiguration which aims to find a good trade-off between energy savings and capacity reconfiguration cost [13].

Energy-Efficient Scheduling of Urgent Bag-of-Tasks Applications in Clouds through DVFS

In this paper, they have proposed an approach for the problem of energy-efficient execution of urgent, CPU-intensive Bag-of-Tasks applications in cloud infrastructure which are likely to be found in domains such as disaster management and healthcare. It utilizes intelligent scheduling combined with the Dynamic Voltage and Frequency Scaling (DVFS) capability of modern CPU processors to keep the CPU operating at the minimum voltage level (and thus minimum frequency and energy consumption) that enables the application to complete before a user-defined deadline. They have proposed a cloud-aware scheduling algorithm that applies DVFS to enable deadlines for execution of urgent CPU-intensive Bag-of-Tasks jobs to be met with reduced energy expenditure. This approach is able to significantly reduce energy consumption of the cloud infrastructure with the extra feature of not requiring virtual machines to have knowledge about its underlying physical infrastructure while not inducing any impact on the Quality of Service offered to clients [14].

Heterogeneity-aware Workload Placement and Migration in Distributed Sustainable Datacenters

In this paper, they have proposed a framework, sCloud, a holistic heterogeneity-aware cloud workload placement and migration approach, which intends to maximize the system goodput in distributed self-sustainable datacenters. This approach maximizes the system performance in terms of system goodput, based on the time fluctuating green power supply, heterogeneous workload characteristics and Quality of Service (QoS) requirements. They have designed an optimization-based algorithm to dynamically place transnational requests to cloud datacenters, with respect to their green power supplies. Furthermore, in order to improve the system goodput, integrate another online algorithm to dynamically migrate batch jobs across distributed cloud datacenters when the green power supplies vary widely at different locations. They have developed sCloud in university cloud testbed and performed considerable assessments with real world climate conditions and workload traces [15].

A Genetic Algorithmic approach for Energy Efficient Task Consolidation in Cloud Computing

In cloud computing, the task consolidation becomes a major research issue for effective utilization of computing resources. In this paper, they have proposed a novel genetic algorithm framework for task scheduling to reduce energy utilization in cloud computing infrastructure. The proposed GA resource allocation strategy has better performance in experimental results over Random and Round Robin Scheduling policies. The proposed the GA-based task scheduling model introduces a suitable codification scheme for chromosome.Furthermore, described making an optimal task schedule and compose elements of the GA scheduling function. To create new population, they have developed a POP_SIZE number of random initial population and calculating the fitness value of individuals. Then the parents are selected using roulette wheel selection method to produce off springs using single point crossover with probability 0.8. A portion of the individual are exposed to the mutation with a probability 0.2. The next generation population is chosen again through roulette wheel selection method. The steady population size has been maintained for a fixed number of iterations. The individual with minimum energy value from the last generation is selected to allocate the tasks to VMs[16].

Energy efficient scheduling algorithm for data centers resources in cloud computing

In this paper, they have developed two distributed and localized intra-cluster and inter cluster VM scheduling algorithms based on energy calculation, resource requirement and availability for cluster formation based on network vicinity among the data servers. The proposed work helps in

the maximizing resources utilization in every server, which helps to develop a strong and competitive cloud industry throughout the world in obtaining energy-efficient environment and the customers satisfaction will be increased through service level agreement assurances. They proposed scheduling algorithms to manage VMs in reducing energy consumption of both the servers and networking devices. Simulation Experimental results in this paper show that, the proposed distributed VM scheduling algorithms helps in substantial reduction of energy consumption in data management and operation of data center [17].

pMapper: Power and Migration Cost Aware Application Placement in Virtualized Systems

In this paper, they have introduced an application placement controller pMapper that reduces power and migration costs, while meeting the performance guarantees. pMapper differs from all existing literature because it addresses the issue of power consumption and migration cost aware application placement in heterogeneous server clusters that support virtualization with live VM migration. They have investigated the viability of utilizing CPU usage-based application specific power models to develop placement algorithms and validates the assumptions through testbed experimentation. They have proposed three dynamic placement algorithms to reduce power consumption and migration cost and experimentally demonstrated the various scenarios in which each algorithm is effective [18].

Energy-efficient Task Scheduling in Data Centers

In this paper, they have proposed a novel VM scheduling mechanism design and implementation to enhance the energy efficient scheduling in cloud data center. In this methodology, they addressed on both load-balancing and temperature-awareness with a final objective of reducing the energy consumption of a data centre. This scheduling scheme selects a physical machine to host a virtual machine based on the user requirements, the load and temperature of the hosts, while maintaining the quality of service. They have validated this proposed mechanism with CloudSim- a simulator, that model data centers provisioning Infrastructure as a Service. The proposed scheduling scheme combines power-aware with the thermal-aware scheduling strategies, significantly reduces the energy consumption of a given Data Center because of its thermal-aware strategy and the support of VM migration mechanisms. Furthermore, comparative study has been done with various scheduling algorithms such as, non-power control, DVFS and power aware ThrMu[19].

Virtual Machine Consolidation in Cloud Data Centers using ACO Metaheuristic

In this paper, they have proposed the AVVMC VM consolidation scheme with an objective of minimizing power consumption and resource wastage by focusing on balanced resource utilization of servers across various computing resources (CPU, memory, and network I/O). They proposed adaptation and integration of the Ant Colony Optimization (ACO) metaheuristic with balanced usage of computing resources based on vector algebra for VM consolidation problem which is strictly NP-hard and computationally infeasible for large data centers. In their simulation results, AVVMC algorithm outperforms existing methods and achieves enhancement in both energy utilization and resource wastage reduction [20].

Title	Algorithm / Framework Used	Parameters or Factors	Conclusion	Future Work
Energy-Efficient Resource Allocation and Provisioning Framework for Cloud Datacenter	Framework for predicting number Virtual Machine (VM) requests	Machine learning clustering and Stochastic theory	predicts the number of VM requests and the amount of resources associated with these requests	To investigate whether VM requests follow certain regular daily trends and rely on that to further improve the workload prediction module.
Energy-efficient Scheduling Policy for Collaborative Execution in Mobile Cloud Computing	Canonical "LARAC" algorithm	Optimal collaborative execution for Energy Efficiency	conserving energy for executing mobile application by using *one-climb* policy for task offloading to the cloud.	Task topology can be extended into more generic graphs like tree, grid, etc and structural properties for optimal task scheduling policy.
Task Scheduling and Server Provisioning for Energy-Efficient Cloud-Computing Data Centers	Greedy Task Scheduling scheme, Efficient Server-First task-scheduling scheme	energy consumption, Task Scheduling and server provisioning	reduce energy consumption and task response time by minimizing the number of servers while maintaining a deadline-based service-level agreement.	Other objectives can be focussed along with task deadline constraint
Dynamic Heterogeneity-Aware Resource Provisioning in the Cloud	Heterogeneity-Aware dynamic capacity provisioning policy, Controller algorithm for Capacity Based Scheduling (CBS)	Heterogeneity, Energy Utilization	heterogeneity of workload and machine to balance between energy savings and scheduling delay, while considering the reconfiguration cost	Considering workload heterogeneity at fine-grained level (per task)

Dynamic Energy-Aware Capacity Provisioning for Cloud Computing Environments	Model Predictive Control (MPC)	Dynamic capacity provisioning, Energy Savings and costs	dynamic capacity provisioning system to control the number of active servers for good trade-off between energy savings and capacity re-configuration cost.	Understanding the flexibility between schedular and capacity controller and handling machine heterogeneity
Energy-Efficient Scheduling of Urgent Bag-of-Tasks Applications in Clouds through DVFS	Dynamic Voltage and Frequency Scaling (DVFS)	CPU-intensive Bag-of-Tasks applications	Cloud aware scheduling algorithm with DVFS to enable deadlines for execution of urgent CPU-intensive Bag-of-Tasks jobs to reduce energy expenditure.	To support different types of application such as workflows and MapReduce
Heterogeneity-aware Workload Placement and Migration in Distributed Sustainable Datacenters	sCloud	System goodput, green power	improve the system performance and green energy usage by self-optimizing cloud workload and resource management	integrating energy storage technique with sCloud for sustainable computing in green data centers.
A Genetic Algorithmic approach for Energy Efficient Task consolidation in Cloud Computing	Genetic Algorithm	Task Consolidation, Energy Utilization	the assigned the jobs to the VMs by minimizing the makespan.	Change in number of initial populations, number of generations, crossover and mutation probability
Energy efficient scheduling algorithm for data centers resources in cloud computing	VM provisioning algorithm, Intra-cluster VM scheduling algorithm, Inter-cluster scheduling algorithm	Resource management and utilization, Energy Efficiency, QoS	Reducing the consumption of energy by switching off redundant servers and by keeping underutilize clusters in sleep mode	Implementing cooling condition of physical servers to improve energy efficiency
pMapper: Power and Migration	pMapper, *minPowerParity*(*mPP*),	power consumption, live VM	reduces power and migration	Task arrival rate and Scheduling
Cost Aware Application Placement in Virtualized Systems	*First Fit Decreasing (FFD), PMaP for Power and Migration*	migration	costs, while meeting the performance guarantees	delay objectives
Energy-efficient Task Scheduling in Data Centers	Critical Host Detecting algorithm, Migratable VM's Detecting algorithm, Target Host Detecting algorithm	Power aware and Thermal aware scheduling strategy, VM Migration, Energy Efficiency	Target host will not be overloaded or over heated or scheduling of VM's with respect to the temperature and CPU utilization of processors	Optimization of proposal scheduling scheme with respect to its performance
Virtual Machine Consolidation in Cloud Data Centers using ACO Metaheurist-ic	AVVMC algorithm based on Ant Colony Optimization (ACO)	Energy consumption, Resource wastage reduction	ACO Metaheuristic base server consolidation mechanism to address both power consumption and resource wastage minimization in large virtualized data centers	Efficient network resource utilization in cloud infrastructure during VM placements and consolidation decisions

V. CONCLUSION

The cloud computing environment provides heterogeneous scalable physical resource on demand. It is important to use these resources in efficient way by developing energy efficient cloud-based resource schedulers. In this paper, we have discussed various energy efficient task scheduling algorithms for better comprehension of the existing research in this area along with possible future work. Energy Consumption is one of the major parameters in efficient resource scheduling. These algorithms are distinguished on the basis of various parameters such as utilization of resources, makespan, response time, energy efficiency, scheduling delays, QoS, workload etc. The main significance is on energy efficient metaheuristic algorithm such as Ant Colony Optimization, Genetic Algorithm etc. These algorithms can be enhanced to make it as an effective algorithm, which can optimize the energy and QoS in the best possible way.

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