A Study on Energy Efficiency Techniques in Cloud Computing

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Abstract

Since its inception, cloud computing has become increasingly popular thanks to its scalability and resource on demand capabilities. The distributed infrastructure of cloud computing (CC) enables users to access resources from any location and at any time. Through the internet, cloud computing offered a number of services, including platform as a service (PaaS), infrastructure as a service (IaaS), and software (SaaS) as a service. Instead of creating his own infrastructure, which requires upfront investment and skill, the consumer uses third-party services. Cloud computing is growing more and more popular due to its availability, reasonable cost, limitless computing power, on-demand services, and high level of service. The service provider increases its resource capacity to fulfil consumer demands for availability and processing power. Large datacenters with large amounts of computers, data, and other auxiliary devices set up the infrastructure required to support cloud computing. The large-scale configuration of the datacenters, which include several computing nodes, results in significant electrical power consumption and greater operating costs. High energy demand was a result of this development in resource capacity. Energy consumption and privacy and security needs are two significant challenges for cloud computing. This study presents a survey on numerous energy-efficient cloud computing methods that use very little resources and power.

Keywords: Cloud computing, Energy, Datacenters, cloud services, Power supply.

Introduction

Since a decade ago, cloud computing has drawn the attention of computer scientists for a variety of reasons. It aims to give consumers dynamic, adaptable computing infrastructure that is also more reliable and of greater service quality. One of the main contributions that a cloud may make [1] is the provision of suitable, adaptable, on-demand service, resource pooling, wide network access, and measured service with a minimum of management work and in a highly customizable way. It is a virtual environment that can replace expensive computing infrastructures for a variety of IT solutions. Because of its special scalability feature, it is a versatile choice that can be scaled up or down depending on the needs of the end user. Depending on the service they require from the cloud, cloud service users or customers can be thick or thin clients.[2] Depending on the services they utilise, users may be charged on a per-use basis. These resources may consist of a collection of real and virtual assets that are accessible from any location at any time in the cloud. One of the basic qualities of the cloud architecture is dynamic. Providers of cloud services provide three types of service delivery.

Software as a Service (SaaS): This offers the application to customers as a service.

When a client accesses the cloud, Infrastructure as a Service (IaaS) provides a computing platform for them. It enables cloud data storage for the customer.

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Platform as a Service (PaaS): It gives developers a platform to polish their applications and assists with using the tools offered by the supplier. A cloud implementation can be classified as either public or private. Private cloud access is unshared and limited to a single user, whereas public cloud access is limitless and shared. There is a significant quantity of storage needed due to the acceptance of cloud computing, the rapid expansion of mobile devices, the emergence of data centre difficulties, and the creation of digital content. This recent computing technology and associated problems such as: global warming, hike in fuel consumption and energy cost need to be investigated. The amount of energy consumed by the ICT equipment in data centers need to be reduced. It has been calculated that the amount of energy consumption by the data centers of the service providers is equal to 1.5% of the power supplied to an entire city [3]. The amount of resources used while hosting cloud applications in a data centre consumes a huge portion of electrical energy, raising the cost of operation and leading to the generation of carbon dioxide [4]. According to a recent calculation, a laptop's energy usage ranges from 60 to 160 kWh and a desktop's ranges from 160 to 400 kWh (assuming they are both used for 2,600 hours annually). Similar to this, 200 watts of server electricity are required to cool down a server (assuming 50 employees use a server, with a PUE of 2.0 and 8.766 operating hours annually) [5]. Furthermore, according to the forecast given in [6,7], by 2020, data centres would release at least four times as much carbon dioxide as they did in 2008. Due to environmental concerns and the requirement to reduce greenhouse gas emissions, energy conservation is crucial in cloud computing. Some data centres have been constructed in high altitudes to lower the power requirements. However, constructing a data centre at a high elevation also creates a number of implementation problems.

As a result, the researcher has long been interested in strategies to lower the energy requirements for cloud computing. There are numerous ways to lower cloud system energy consumption. As follows: [8]Hardware that is energy-efficient (i) Intel and AMD both offered techniques to cut down on power and heat production, called "Speed Step" and "Power Now," respectively. This issue is still unresolved because energy use is inversely proportionate to resource use. Consequently, software-based energy-saving strategies were created.

(ii) Energy-Aware Scheduling: Several energy-conscious scheduling techniques, including Dynamic Voltage Scaling (DVS), Dynamic Voltage/Frequency Scaling (DVFS), and Request Batching, have been developed. However, none of these plans considerably optimise energy. (iii) Consolidation: The consolidation technique entails the consolidation of servers, tasks, energy-related tasks, task-based energy consumption, and energy-aware tasks (ECTC).

Each of these approaches has advantages and disadvantages.(iv)Energy Consumption in Cluster of Servers: Basically, it aggregates system demand before determining the bare minimum of servers required to complete the operation. Some methods can only distribute the load statically and are limited to homogeneous servers. The VM mapping problem, however, is not fully taken into account in some solutions. In order to reduce this power dissipation in a group at server clusters, new strategies are developed that take the system's throughput and latency into account. Consequently, reducing energy consumption in a data centre is currently a prominent topic in the IT sector. Therefore, a brief overview of current energy efficiency trends and the potential for future study have been highlighted in this paper.

2. Related Work

The research community is paying a lot of attention to a number of topics regarding green ICT and energy reduction in contemporary cloud computing platforms. Building energy consumption

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models, creating energy-aware costs, managing workload variation, and attempting to create an effective trade-off between system performance and energy cost are just a few more initiatives that have been done. For determining the overall cost of utilisation and ownership in cloud computing environments, the authors of [9] established a cost model.

For this computation, they created quantifiable metrics. Their calculation granularity, however, is predicated on a single piece of hardware. In the recent years, research has also been done on energy management strategies in cloud systems. Dynamic Voltage/Frequency Scaling (DVFS) is a method for adjusting servers' power consumption that was described in [10]. DVFS modifies CPU energy usage based on workload. The CPUs are the only devices included, though. Therefore, it is necessary to investigate how specific VMs behave. These can be accomplished by keeping an eye on the energy profiles of specific system elements, such as the CPU, RAM (running), disc, and cache.

Due to the inbuilt card controllers that are used to wake up the remote nodes, Anne et al. [11] noticed that nodes continued to utilise energy even when they were switched off.

For changing between the server's operational modes, Chen et al. [12] suggested two energy models. To calculate the energy used in the idle state, the sleep state, and the off state, as well as to switch between these stages, they analyse the actual power measurement made at the server's AC input. But if load increases unexpectedly, switching between power modes can result in poor performance. Furthermore, load balancing allows the group of servers that handle the load to change continuously, which keeps most servers' idle times to a minimum.

There are various authors who have put forward the power modelling methodologies. The workload and CPU energy utilisation were found to be correlated over time by Buyya et al's power consumption model [13]. Additionally, Bohra et al.'s [14] power consumption model suggested that component utilisation and system power consumption were correlated. For the entire power usage, the authors developed a four-dimensional linear weighted power model.

According to Chen et al.'s research, [15] the essential unit for energy profiling is a single job executing in the cloud. Using this method, Chen and her colleagues discovered that scheduling overhead prevents the combined energy consumption of two jobs from equaling the sum of their individual energy consumption. They developed a power model for overall energy use that emphasises the availability of resources for storage, processing, and communication.

However, other research initiatives have also been conducted, focusing primarily on virtualization, to reduce energy use in cloud systems. By allowing several virtual machines (VMs) to run on a single physical host and performing live migrations to make the best use of the available resources, this technology enables users to overcome power inefficiency. Yamini et al. suggested cloud virtualization as a feasible strategy to lower energy use and global warming in [16]. Instead of employing numerous servers to provide service for multiple devices, their method uses fewer servers.

For us, the most pertinent power modelling methodologies are those put forth by Pelley et al. [17] for the physical infrastructure (power and cooling systems) in data centres. They developed initial models that aim to fully represent a data centre.

A critical analysis of the state-of-the-art research on energy-efficient dynamic allocation of virtual machines to hosts in a datacenter as per the varying workload demands of various applications running on the virtual machines is provided by Choudhary et al. [18], and the literature review suggests that further optimising the placement of the virtual machines can be done using live migration. In order to provide a deadlock-free resource allocation, this study proposes a method

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for optimising virtual machine placement via live migration utilising dynamic threshold values that focuses on multidimensional resources. The objective is to decrease datacenter energy consumption by increasing the total utilisation of computer resources.

Before making any changes to the infrastructure, Puhan et al. [19] analyse the current situation. Reducing data centre carbon emissions is one of the main research problems that experts in cloud computing have been attempting to solve. By looking into all potential areas in the cloud infrastructure responsible for the significant amount of energy consumption, this paper discusses contemporary systems designed to improve energy efficiency in the case of large-scale cloud computing infrastructures without compromising the quality of services and performance.

Chen and others [20] The cloud computing data center's storage and computational capacities have been severely hampered by the rapid development of data, which also results in significant energy usage. Hadoop has not been energy-efficiently optimised as the primary framework for big data storage and computation in the present cloud computing data centre. This article examines essential technologies for optimising the energy efficiency of Hadoop framework components in the data centre, including the most recent research findings for energy-efficient YARN scheduling techniques and energy-efficient Distributed file system (HDFS) storage strategies.

Albarracin and others [21] The highly scalable cloud computing model provides resources as needed. Because of its decentralised infrastructure, customers can access all available resources. It provides its customers with high-quality, dependable materials as a service over the internet. It is a step towards green computing, allows clients to access resources in a dispersed fashion, and does away with the installation and implementation processes Instead of using standard computing paradigms, it takes energy, excessive heat, power consumption, etc. into account, making it environmentally friendly.

3. Energy Efficient Techniques in Cloud Computing

Energy-efficiency measures at the data centre level can be categorised as hardware-based, infrastructure-based, software-based, and location-based. Author [30] discusses various power management strategies at the hardware and software levels, while [29] focuses more on energy-saving strategies at the software level. There are five groups of additional software-based energy optimisation techniques: resource management, dynamic voltage and frequency scaling, parallel programming, and workload consolidation. By using the most recent resource management and task consolidation strategies, we will expand on the work of [29] in this survey.

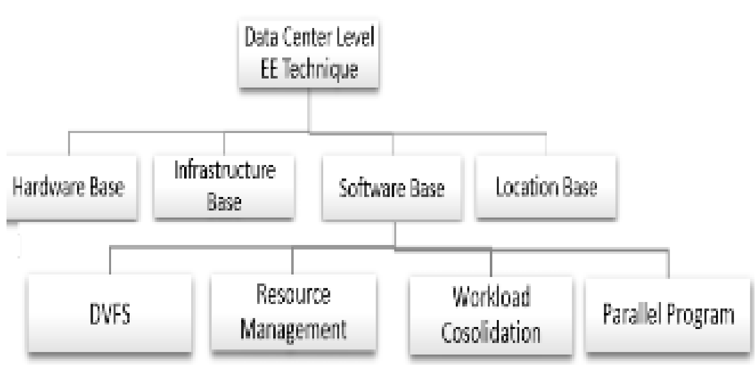

Figure 1: Energy optimization techniques at data center level

A. DVFS

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The practise of purposefully reducing the processor's performance when it is using too much power and the task can be completed processing at a lower frequency. Frequency and voltage are directly related. Saving this energy will have a significant influence on energy reduction because it has been found that servers use roughly 70% less energy while they are idle. This issue can be successfully resolved with DVFS. DVFS was primarily created and intended for embedded systems' energy efficiency. However, this can be put into practise and is one of the best energy-saving strategies for servers that run lots of computations. For operations that require a lot of input and output, this is thought to be bad. Jacob Leverich proposes a technique for turning on some resources and performing work on them while keeping the others off to conserve energy. Consolidation and DVFS vary in that consolidation is used universally, whereas DVFS is only used locally [31]. However, Wilies argues that using all available resources will result in faster completion of the task and greater energy savings. Energy efficiency attained with DVFS depends on the SLA type; a stringent SLA results in a low energy savings of 1.11% while a relaxed SLA is more successful, saving 6.69% of energy

While memory and input/output intensive tasks are not appropriate for DVFS, CPU-intensive tasks can be successfully completed with it [32]. When a request is received, it is compared to the table's history to determine if it is CPU- or I/O-intensive. The frequency is changed following this calcification.

B. Resource Management

Resource management is the act of selecting computing, storage, and network resources wisely and assigning them in response to a single or group of requests in order to satisfy the user's performance goals [33]. Energy efficiency places a major emphasis on resource management. By examining SLAs, it is able to determine the type of request and then assign the best resources in terms of performance and cost. The scheduling of resources is the essence of management. The scheduler looks at and analyses the system's current status when a request is made to determine an optimal resource allocation [34]. Scheduling primarily involves managing virtual machines. The management of virtual machines includes VM migration. Three reasons were addressed by VM migration: performance, load balancing, and energy efficiency. But since energy efficiency is our main concern, we'll focus on it.

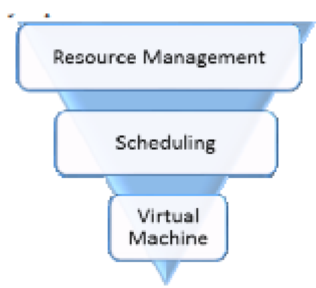

Figure 2: Resource Management Hierarchy

In [35] proposes energy-conscious VM migration methods based on the firefly algorithm. This method is based on three principles: (I) because fireflies are asexual, they are attracted to each other regardless of gender; (II) less light fireflies will gravitate towards brighter ones; and (III) as distance increases, the attractiveness of the brighter fireflies decreases. (III) Setting the objective functions to be improved affects how bright the firefly is. The energy-aware virtual machine

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migration performed by the Firefly method involves moving the VM from the busiest active node to the least busy active node. There are four steps in deciding to migrate. Selection of the most loaded active node, choosing a VM from the loaded node, migrating to the destination node, and updating the distance. To choose a loaded node, computational energy must first be determined, and a list must then be formed. Next, node computation time must be determined, and values must be entered into a table. In the third step, attractiveness is evaluated based on CE values, with the lowest CE value being listed first. In step four, a node is chosen based on its CE value that is closest to the computed distance after a distance is determined and a list is obtained. Create a list in decreasing order after computing the load for each unique VM. To restart the process, move the top VM from the VM list to the top node on the AI list and change the distance. Reduce the energy use of resources like memory, CPU, network, and storage to increase energy efficiency. The suggested tactics make good use of the resources that are available. Idle resources are put into sleep mode or turned off to save energy. To maximise network energy, traffic on the network is kept to a minimum. High traffic VMs are moved to the same PM to reduce network traffic. By reducing network traffic, fewer network components will be active, which will save a significant amount of energy [36].

The author of [32] proposes a method called residual resource fragmentation since VM on PM are not being used to their full potential. Although there are many resources, processing and memory resources are what we are most interested in. Resource fragmentation is the condition in which a resource's use is restricted or prevented by another resource. In this study, the author essentially combines the dispersed resources into each individual PM and brings them together with the fewest possible PMs. If a request to create a new virtual machine (VM) with a processing load of more than 40% is submitted at two o'clock in the afternoon, it will not be fulfilled. But if we pool our 85% processing power at two o'clock in the afternoon, we can fulfil requests for the formation of additional virtual machines that are higher than 80%.

A plan based on virtual machine consolidation was put up in [37] by the author, which would reduce the number of active servers by dynamically consolidating virtual machines on a small number of servers and take advantage of the low energy proportionality of frequently used hardware. In a virtualized environment, VM consolidation is an approach to maximise resource utilisation while minimising the energy requirement. The majority of the research ignores the data center's cooling and network energy requirements. When consolidating VMs, keep in mind both the network data structure and cooling requirements. Fever racks and routers are utilized without compromising SLA to improve energy efficiency.

C. Workload Consolidation

Data centres are physically dispersed throughout a region. A request is routed to the data centre that is geographically closest when it is received. This shortens turnaround times by reducing network delay. To conserve energy, the request is attempted to be fulfilled inside the data centre utilising the active PM. When servers in data centres are idle, a significant amount of energy is consumed—up to 50% more than when they are operating at peak efficiency [35]. This high proportion results from the server being idle or underloaded for 70% of the time. An efficient method of selecting the appropriate node for request processing is required to save this energy. It takes planning to turn the underloaded node off or into a low energy condition. These are just a couple of the decisions that should be made in this strategy, such as when to switch off and when to wake up. Similar to this, if a new request is received and there isn't a server available to fulfil

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it, a new server needs to be activated or woken up. This flexibility allows for the placement of several requests on a single server in order to increase resource utilisation and reduce resource demand [38] [38] [39].
Consolidating multiple VMs onto a single PM in order to reduce energy usage is known as VM consolidation. The challenge with online bin packing is the consolidation of VM on fever number of pm. Given that the process is real-time and because pm is a bin and VM is an object, the decision-making process must be rapid and effective in terms of both performance and resource utilisation [40]. According to resource need, VM come in a variety of sizes, and bins vary in terms of the resources they can hold. It is attempted to use the active server when assigning VMs to PM as opposed to turning on or waking up a new server. How it will choose the PM from among many to receive the request. One method is to place the request on the PM that has the least amount of available space to accommodate the request. Using this method, the maximum amount of resources are utilised while still leaving a significant amount of room on the other PM for future requests. However, the overhead associated with placing a server into sleep mode and then waking it up is negligible [41]. Aggressive consolidation may result in energy inefficiency and performance impairment. Because a device's performance efficiency and speedup are reduced and its cooling requirements increase when it is operating at maximum capacity.

D. Parallel Programing

Systems with several cores increase performance at the expense of more processing power. One of the most difficult tasks in a computer system is to handle the quickest processing unit in an efficient manner. There are numerous methods for reducing the energy usage of these multicore/parallel systems. All of these methods increase energy usage [42, 43] by sacrificing throughput in order to maximise performance per watt. The term "parallel programme" refers to software optimisation, which includes runtime and code optimisation. Programmes running in parallel optimise code. Programmers should be well-versed in the underlying hardware to achieve energy efficiency.

Table 1. Different Energy Optimization Methods

Method	Categories	Technique	Resolves
Data Centre Resource Management	Local and Global Policies	Virtualization	Sequential optimization by adressing it through the concept of limited lookahead control
Scheduling for multi-tier web applications	Virtualizing heterogeneous systems	Virtualization	Decreases power consumption by maintaining performance for multi-web applications
Power-aware dynamic placement of applications	Dynamic Virtualization	Continuous Optimization	Power-aware dynamic placement of applications in

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			interaction with a virtualized heterogeneous environment
Dynamic virtual machine consolidation	Dynamic VM consolidation based on estimation stability	Resource demands by utilizing the time-varying probability density function	Resolves resource optimization for small applications
Dynamic Voltage and Frequency (DVFS)—Proposed	Single and Multi-server	DVFS, based on workload	Saves power and resolves resource optimization issues based on workload for servers placed locally and globally

4. Challenges

Two areas—migration to a single virtual machine and migration to a dynamic virtual machine—are examined to identify the key difficulties.

Migration of a Single Virtual Machine, Section 4.1

The data center's workload, system consumption, and flexibility can all be improved using virtual machines. However, issues like resource waste, network congestion, and consolidation still exist and will lead to server hardware failures. Researchers employ single virtual machine migration to define a data centre with certain characteristics [22–23]. Similar to [24], [22-23] experimented with increasing server average utilisation. Similar efforts were made by [24] to raise server average utilisation, experiment with previous data to forecast future server demands, and migrate virtual machines in response to changing conditions. Using historical data to forecast future server needs and moving the virtual machine to meet those needs. The primary difficulties in moving virtual machines in wide-area networks are unstable length and high latency. As a result, by suggesting a three-phase strategy, [25] become substantially more responsive in wide area network transfer. Most importantly, virtual machine migration is frequently used to reduce power consumption by condensing idle desktop virtual machines [26]. Additionally, algorithms have been created by researchers with the aim of reducing power mode transition delay [27]. The primary difficulties in moving virtual machines in wide-area networks are unstable length and high latency. Therefore, by suggesting a three-phase strategy, [26] get substantially more responsive in wide area network migration. Most importantly, virtual machine migration is frequently used to reduce power consumption by condensing idle desktop virtual machines [26]. Additionally, academics have created methods to reduce power mode transition latency [27].

4.2. Migration of a Dynamic Virtual Machine

Virtual machine migration (VMM) is the transfer of some or all of a virtual machine's data from one location to another while maintaining uninterrupted operation. Live migration and non-live migration are the two ways that VMM is structured. In a non-live migration, the virtual machine is paused during the earlier migration phase and is dependent on whether or not it needs to continue

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providing operating services during the subsequent migration. If it is suspended, the states will be transferred to the target site, moving the machine data from one location to another while maintaining the existing services. Live migration and non-live migration are the two ways that VMM is structured. In a non-live migration, the virtual machine is paused during the earlier migration phase and is dependent on whether or not it needs to continue providing operating services during the subsequent migration. The states will be relocated to the target site if it is suspended. Since no open network connection is kept during migration, all connections are restored after virtual machine continuing, as seen in Figure1.

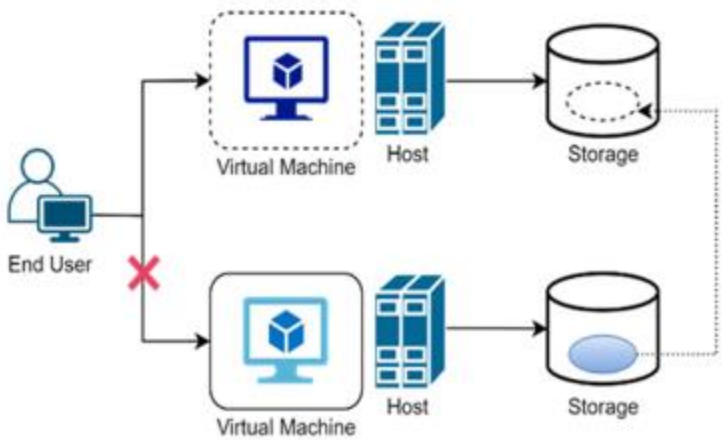

Figure 1. Non-Live Migration

As demonstrated in Figure 2, live migration is the transfer of a virtual machine running on one physical host to another host without interfering with regular operations or causing any stoppages or other unfavourable effects for the user.

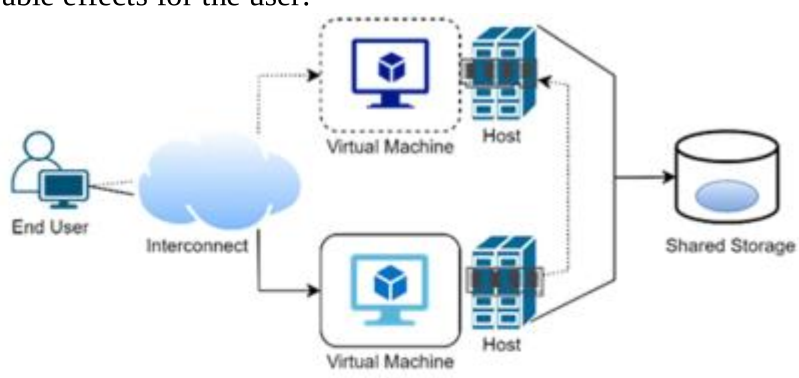

Figure 2. Live VM Migration

Data transfer memory and persistent network connections are two issues with live migration. However, moving dynamic virtual machines has some difficulties, including taking into account numerous hosts and multiple virtual machines [28]. Other difficulties include network connectivity, memory data migration, and storage data migration.

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5. Conclusion

As we know that cloud computing provides availability of the resources access to the users anytime from anywhere so for this huge amount of datacentres requires which consume lots of electrical power. So to mitigate this various energy consumption techniques has been developed and implemented. In this study, we present the numerous energy consumption approaches that were included in our survey report, which focused primarily on four key energy efficiency techniques: parallel programming, resource management, work load consolidation, and DVFS. We made an effort to incorporate the best and most recent energy efficiency approaches in these four software-based technique categories. In the future, we will build on this work by carefully examining and studying the strategies for workload consolidation and resource management. The majority of recent research relies on these methods. Compared to other approaches, these techniques have a high margin for energy efficiency.

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