System Migration from On-Premise to Cloud in Small and Medium-Sized Enterprises (SMEs): A Critical Review and Problem Formulation of Energy Efficiency in Virtual Machines and Containers

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ABSTRACT

Background: Cloud migration involves transferring IT systems from on-premise data centers to cloud-based data centers. This process raises several issues and concerns from both the perspectives of cloud service providers and consumers.

Objective: The objective of this study is to systematically review the literature on cloud migration to identify challenges and solutions, particularly focusing on energy efficiency in data centers and the difficulties faced by small and medium-scale enterprises (SMEs) during cloud migration.

Methods: A systematic literature review was conducted using Scopus, Web of Science, and Google Scholar databases. Following specific search tactics and selection criteria, 36 out of 964 research articles were selected using key terms and the PRISMA protocol. The thematic synthesis of the evaluation of consolidation algorithms was employed to assess energy efficiency improvements in data centers and the challenges in the cloud migration process for SMEs.

Results: The review revealed that most articles explored various techniques to enhance the energy efficiency of cloud data centers. However, they often overlooked the relationship between migration time and power consumption. Additionally, the proposed algorithms showed inconsistencies in performance metrics. There is a notable lack of models and frameworks tailored for SMEs to address cloud migration challenges effectively.

Conclusion: The study highlights the need for more comprehensive approaches that consider both energy efficiency and migration time. It also emphasizes the necessity of developing robust models and frameworks to assist SMEs, particularly in developing countries like Ethiopia, in overcoming cloud migration challenges. The use of virtualization and containerization techniques in energy-efficient cloud migration was identified as a key area for future research and development.

Keywords: Cloud computing, Migration, VM consolidation, energy-efficiency, SMEs, Containerization

INTRODUCTION

Business organizations use various Information and Communication Technologies (ICTs) to support their organizational processes and communicate and collaborate with other business organizations. This is done for delivering the goods and services to the customers at their door, like in e-Commerce. To exploit the advantage of ICTs for their business processes, the organizations are responsible for establishing their own data centers, managing and controlling the data center activities like maintenance, power management, security, and procuring or developing the necessary software components, systems, and utilities.

It is vital and possibly important to say that all business organizations cannot afford or establish their own ICT infrastructure or data centers, along with technical human resources. Today, scientific agencies and international treaties encourage an energy-efficient ICT system to minimize greenhouse gas emissions. European countries reported that the climate change data center will be developed further in collaboration with numerous international agencies [1]. The United Nations report [2], [3] indicates that growing climate change impacts are experienced across the globe. The main message is that greenhouse gas emissions must fall. The 2022 Emissions Gap Report (EGR) indicates that society and business must quickly adapt to the climate crisis, as there is no definitive solution available. The high cost of power consumption hampers the profit margin of organizations, especially in the service sector, like IT industries, software companies, online service sector organizations, and manufacturing hubs. In the era of

Industry 4.0, various emerging technologies such as big data, the Internet of Things (IoT), virtual reality, augmented reality, cloud computing, and other advanced technologies proposed by researchers to enhance and advance the quality of services provided by enterprises. The greenness of the services is one of the important quality parameters.

NIST defines: Cloud computing "is a model that enables ubiquitous, convenient, on-demand network access to a shared set of configurable computing resources (such as networks, servers, storage, applications, and services)) that can be provisioned quickly and is delivered with minimal administrative effort or service provider interaction" [4]. Consumer organizations can benefit economically from the concept of cloud computing, which provides resources that can be consolidated as a service on the Internet and offers many economic benefits. Depending on the type of resources cloud computing provides, distinct layers can be defined. In this technology architecture, the bottom-most (lowest) layer of the cloud service models provides basic infrastructure components such as CPUs, memory, and storage. It is henceforth often denoted as Infrastructure-as-a-Service (IaaS). On top of IaaS, platform-oriented services allow the hosting environment to be tailored to a specific need. Finally, the topmost layer provides its users with ready-to-use applications, also known as Software-as-a-Service (SaaS) [5].

To harness the full potential and power of cloud computing technology, businesses must think about cost-effective, on-demand scalable, and robust solutions for their ICT needs, i.e., data centers. These data centers can be either on-premise/Native or Cloud-based. To alleviate the limitations and challenges of the native data centers, such as on-demand scalability, affordability, high-end availability, etc., an alternative data center technology is needed. As an alternative option, migrating data, applications, and other necessary software from native or on-premises systems to a cloud server is a complex process. This involves a cautious assessment of the business enterprise's IT strategy, the feasibility of migration, and selecting a suitable or most feasible cloud service provider. Based on the defined criteria of an organization, careful strategic planning, designing, and experimentation with the data center's needs and their contextualization are essential before migrating to the cloud environment.

Planning, designing, and experimentation can lead to numerous types of cloud migration, ranging from relatively simple rehosting (also known as lift-and-shift) operations to more complex re-architecting initiatives during which apps are rebuilt to harness the power of cloud computing APIs and several options in between. Researchers in study [6] say a data center or ICT center is an architecture that integrates network communication, storage, and high-performance computing. This can provide users with various storage, computing, and network services. To meet the demand of cloud consumers, cloud service providers install thousands of physical and virtual servers in their data centers to provision and provide the requested resources on a pay-per-use model for cloud users. On the other hand, large-scale virtualized cloud data centers consume huge amounts of energy, leading to high operational costs and the emission of significant amounts of greenhouse gases. In today's fast-changing world, focus on green computing, i.e., green approaches, is gaining popularity for cloud computing service delivery, and resource utilization has been increasing in the past few years. As discussed in a study [7], green computing is concerned with supporting personal computing and business-oriented critical computing needs sustainably. This can be defined as minimizing strains and impacts on resources and the environment. Specifically, green computing focuses on enhancing or preserving computing performance in company data centers while lowering energy use and carbon footprints.

Cloud data centers use a technique called consolidation to save energy and improve resource use. This involves moving some or all Virtual Machines (VMs) to different physical machines. By carefully choosing which VMs to move and where to put them, consolidation allows data centers to turn off unused physical machines or put them in a low-power mode [[8]. Consolidation solutions can be investigated to reduce the number of physical computers in cloud data centers and achieve a particular degree of energy efficiency without going against the terms of the service agreement (SLA) in order to save on power consumption and operating costs. This paper's primary goal is to conduct a critical analysis and evaluation of the many strategies and tactics used to reduce cloud data centers' power usage. The difficulties associated with the migration process and the models put out by different researchers are also examined and analyzed in this work.

LITERATURE REVIEW

Related Works or Literature review section is optional. This section may only be available if the explanation related to previous research is not sufficient if it is only shown in the introduction. A literature review is a critical, analytical summary and synthesis of the current knowledge of a topic. It should compare and relate different theories, findings, and so on, rather than just summarize them individually. It should also have a particular focus or theme to organize the review. The length of this section commonly is between 300 – 600 words.

Use sub-heading accordingly, the maximum depth of the subheading is Subheading 3. Please Use the Microsoft Word template style included in template, e.g.: JISEBI Author Name, JISEBI Abstract text, JISEBI Heading 1, etc. All Style for manuscript layout is available in this template.

Virtualization

Example of Subheading 2. Researchers in [9] describe the virtualization has become a critical tool across many information technology fields, particularly in cloud computing. Virtualization essentially creates simulated versions of computer resources, like servers, operating systems, and storage. This technology allows a single physical resource to be divided and run multiple isolated environments. A software layer called a hypervisor is key to managing and controlling access to this pool of virtual resources. As discussed in [11] a hypervisor is a layer of system software that resides between the hardware resources and the operating system. Which manage and segregate virtual machines (VMs) running on PM in a secure setting.

According to a study [10], virtualization merely delivers virtual resources and conceals the physical resource information for high-level applications. A particular PM's resources are all virtualized, enabling resource sharing amongst several VMs within of it. Xen, ESX, Oracle Virtual Box, Microsoft Hyper-V, and kernel-based KVM are a few of the widely used virtual computing frameworks. Additionally, it provides a feature called VM Live Migration, which enables downtime-free VM migration between PMs.

Virtual Machine Placement and Consolidation

A study [12] says the cloud has revolutionized how businesses work. Cloud computing has enabled greater efficiency and flexibility in IT operations with the ability to provide on-demand access to virtual machines. Service Level Agreement (SLA) violations occur in cloud computing environments when a physical system overloads to the point where it is unable to support the resource demands of virtual machines [13]. Furthermore, cloud data centers' high-performance servers need a lot of electricity. Utilizing live virtual machine migration, dynamic VM consolidation technology maximizes resource efficiency and reduces power usage. There are two forms of virtual machine migration; live migration and non-live migration patterns. Applications that are currently operating during VM migration are not suspended during live VM migration, and there is either no disruption or very little interruption during this time. The VMs are not resumed in the non-live VM migration pattern until they have not been fully migrated to the destination PM. [14].

Organizations and individuals can access processing power using cloud computing technologies without having to set up and manage their own IT infrastructure. The cloud is realized as a massive energy consumer on a large scale. Multiple virtual machine instances can be hosted on a single physical machine thanks to virtualization, also known as containerization. The question of how to move an unused server to low power (hibernate/standby) is a topic of intense research attention [15]. Migration is typically a pattern in which a minimum number of physically active machines can host several virtual machines (VMs). We refer to this as VMC, or VM Consolidation. In addition to minimizing energy use and complying with contract violations, VMC must adhere to the standards for service quality [8].

Four essential phases are needed for dynamic virtual machine consolidation, according to a study [7]: 1) figuring out when a host needs to have one or more virtual machines moved from it because it is overcommitted; 2) finding new locations for selected VMs to migrate from overloaded and underloaded hosts; 3) choosing which VMs to migrate from overloaded hosts; and 4) deciding when a host is deemed underutilized, leading to a decision to migrate all VMs off that host and hibernate the host.

Both heuristic and meta-heuristic algorithms named HET-VC (Heuristic Energy and Temperature based VM Consolidation) and FET-VC (Firefly Energy and Temperature aware based VM Consolidation) were suggested by study [16]. In this study six factors such as energy efficiency, number of migrations, SLA (Service Level Agreement) violation, ESV, time, and space complexities were examined in relation to the suggested methods. According to this study's validation test conducted in the CloudSim simulator, reveal that energy consumption was reduced in HET-VC and FET-VC by 42% and 54%, respectively. Additionally, with HET-VC and FET-VC, respectively, there were 44% and 52% fewer virtual machine migrations. According to study, SLA breaches can be improved by 62% and 64% with HET-VC and FET-VC, respectively. Additionally, with HET-VC and FET-VC, the energy and SLA violations (ESV) improved by 61% and 76%, respectively. Additionally, under HET-VC and FET-VC, SLA Violations (ESV) improved by 61% and 76%, respectively.

A novel VM consolidation approach called ABSO was presented in a study [17]. It starts by generating a population of possible VM allocations, where each potential VM allocation is represented by a particle. Next, a fitness function that takes into account the energy usage and VM allocation performance is used to evaluate the particles. ABSO, a mix of beetle swarm optimization (BSO) and particle swarm optimization

(PSO), is intended to reduce a cloud data center's energy usage while still satisfying the virtual machines' performance needs. Results indicated that, in comparison to other cutting-edge algorithms, ABSO might save a cloud data center's energy usage by as much as 20%.
Adaptive thresholds utilizing the VM consolidation algorithm were proposed in a study [18] to categorize the hosts in the data center. Accordingly, the hosts were categorized into overload, medium-load, and low-load. Suppose the utilization of the hosts is beyond the maximum adaptive threshold. In that case, it's included as an over-utilized host. In contrast, if the utilization level of the hosts was less than or equal to the predefined minimum threshold, it was considered an underloaded host. The study does not clearly specify any VM selection or allocation criteria. Also, the SLA conditions are overlooked in the proposed algorithm. The number of PM, VM, and tasks considered in the study is very small and cannot be used to generalize the results produced by the proposed algorithm.
As mentioned in the study [18], the VMs running on an overloaded host should migrate to a medium-loaded host to minimize the SLA violation. Consequently, the VMs running on under-utilized hosts also migrated to other medium-loaded hosts and changed the host's status to a power-saving mode to minimize the power consumption of the data center. The second important step in the proposed VM consolidation algorithm was selecting the VMs from over-utilized hosts. The researchers proposed it based on the types of tasks running on VMs on overutilized hosts. The tasks running on VMs can be either CPU-intensive or memory-intensive. VMs with maximum CPU or memory utilization were the best candidates to migrate to medium-loaded hosts. In this, they proposed a new VM selection model called MRCU (Maximum ratio of CPU utilization to memory utilization), which selects VMs with the highest CPU-memory utilization ratio for migration when CPU-intensive tasks overload a host. On the other hand, the virtual machine with the highest memory utilization was selected for migration if the memory-intensive tasks overloaded the host. But all VMs running on under-utilized hosts must be migrated to medium-loaded hosts to minimize power consumption. The CloudSim simulator on both the Google Cloud workload and Planet Cloud workload datasets validated the proposed algorithm. The proposed algorithm performed better than benchmark algorithms regarding power consumption, SLA violations, and the minimum number of VM migrations. The proposed algorithm considers only the power consumption of the CPU. On the other hand, the effect of the number of VM migrations was not considered as a parameter to assess how well the suggested algorithm performed.
A study explored using machine learning to predict CPU usage for individual virtual machines (VMs) in a cloud computing environment [19]. This prediction was then used to migrate VMs to different hosts, aiming to save energy. While the simulation showed promising energy reduction (up to 26% compared to a non-machine learning approach), the study involved a limited number of VMs, and further research with larger scale is needed for definitive results.
The utilization prediction-based VM consolidation approach (UPVC) is a new VM consolidation algorithm that Awad et al. proposed in their study [20]. UPVC is a prediction-based algorithm that uses utilization prediction to identify overloaded and underloaded hosts. UPVC then migrates VMs from overloaded to underloaded hosts to reduce energy consumption. UPVC utilized minimum migration time for VM selection and power-aware best fit decreasing algorithm for destination host selection, as proposed by [21]. The authors evaluated UPVC using a simulation study. The simulation results showed that UPVC could reduce the energy consumption of a cloud data center. In this, the number of VM migrations and SLA violations during the consolidation process were also minimized compared to other benchmark algorithms.
Over-migrating virtual machines can degrade application performance due to runtime overhead. To address this issue, research [15] developed a normalization-based VM consolidation (NVMC) strategy to bring virtual machines online while minimizing power consumption, SLA violations, and the number of VM migrations. The proposed NVMC approach uses resource parameters to identify overutilized hosts in virtualized cloud environments by considering capacity comparisons and cumulative total availability (CATR) between VMs and hosts. Cumulative demand-to-total ratio (CDTR) values were utilized to identify the destination host on which to place the VM, selected from over-utilized and under-utilized hosts. Normalized resource parameters were used to migrate VMs to eligible hosts based on these criteria. To assess how successful this approach was, experiments were conducted on many VMs using PlanetLab workload tracing. The results show that NVMC outperforms other approaches with significant improvements in power consumption, SLA violations, and the number of VM migrations. [22]

Containers and Consolidation

A container is a lightweight OS-level virtualization technique that allows running an application and its dependencies in a resource-isolated process. Based on the host's usage rate, the quantity of containers to be moved, and the state of the host or virtual machine at the destination, a study [22] suggested container consolidation. The goal of this framework is to reduce the number of active servers and consolidate containers in order to address energy efficiency concerns in the context of Container as a Service (CaaS). Four sets of simulation tests were run for this study in order to assess the effect on data center energy consumption and system performance. The study's findings demonstrated that when the largest container is chosen to migrate (MU), the correlation-aware placement algorithm (MCore), with 70% and 80% as under-load and over-load limits, performs better than alternative placement methods.

Researchers in a different study [23] came to the conclusion that operating containers on bare metal hosts without a guest operating system has various benefits, including good application performance because there is no hardware emulation layer separating the containers from the host server. This study presents a method for allocating and migrating containers that takes user quality-of-service criteria into account when a container is moved from one host or virtual machine to another. Furthermore, the issue of energy inefficiency resulting from underutilization of servers is also explained. The simulation's findings indicate that using container migration rather than virtual machines (VMs) results in lower energy usage and a shorter migration time, both of which improve QoS and lower SLA violations.

A study [24] suggests that the lightweight container consolidation technique can effectively use the real system's processing resources because of the overhead of virtual machine operations. Additionally, by lowering the number of active servers, it can reduce the energy used in cloud data centers. However, the study's only factors were CPU use and SLA problems. According to a study [25], operating system isolation during process execution is the major emphasis of lightweight virtualization, also known as containerization, which is gaining popularity in the cloud data center space. This strategy uses containers to greatly increase mobility and energy efficiency in a cloud application deployment environment by encapsulating the runtime contexts of software components and services.

METHODS

For this systematic review, a search strategy for identifying and compiling relevant research papers was developed. This search strategy was tailored to the Scopus, Web of Science (WoS), and Google Scholar databases. The Google Scholar database is a free tool for searching research articles, which contain both relevant and irrelevant documents [26]. Consequently, the articles retrieved from that database were checked for quality. Articles published by different journals were validated to identify whether they were indexed in Scopus or/and WoS and should be considered for the review.

The primary search terms used were" challenges" OR "problems" OR" contributions" OR "on-premise data center" OR "off-premise data center" OR "native data center" OR "cloud computing" OR "energy efficiency" OR "greenness" OR "VM consolidation" OR "virtualization" OR "containerization consolidation" AND "migration".

The secondary search terms were" small scale" OR "medium scale" OR "enterprises".

To search for relevant articles, the papers/articles had to comply with our search criteria from the paper title, keywords, or abstract, and the studies that satisfied the following inclusion and exclusion criteria were included in the review process.

The inclusion criteria were determined as follows:1) Research papers published in peer-reviewed journals only; 2) Studies that focus on cloud migration and VM consolidations; 3) Research reported in English; 4) A full-text article; 5) Studies published between the years 2018 and 2023

The exclusion criteria were determined as follows: 1) Studies published in another language rather than in English, 2) Articles that can't be fully accessed, 3) Duplicate articles, 4) Articles retrieved from journals that are not indexed in Scopus or/and Web of Science.

Following an extensive review of all acquired papers/articles, only those that satisfied the predefined criteria for inclusion and exclusion in the context of cloud migration and VM consolidation were considered. In this study, PRISMA [27] methodology was employed, and only the articles that specifically addressed the topic of this systematic review were obtained. The entire search process is visually presented in Figure 2.

Using our search tactics and selection criteria, we discovered 964 papers from three databases. Using established search terms, the Scopus database returns 153 hits, the Google Scholar database returns 626 entries, and the Web of Science database returns 185 articles.

All of the searches covered the years 2018 through 2023 and only turned up English-language articles. The search was primarily concerned with mapping the body of knowledge on computer science-related topics such as cloud migration and VM consolidation strategies. The search wasn't carried out on any articles published before 2018. Most of the search was done on journal publications, including paper reviews, conference papers, research articles, and reports.

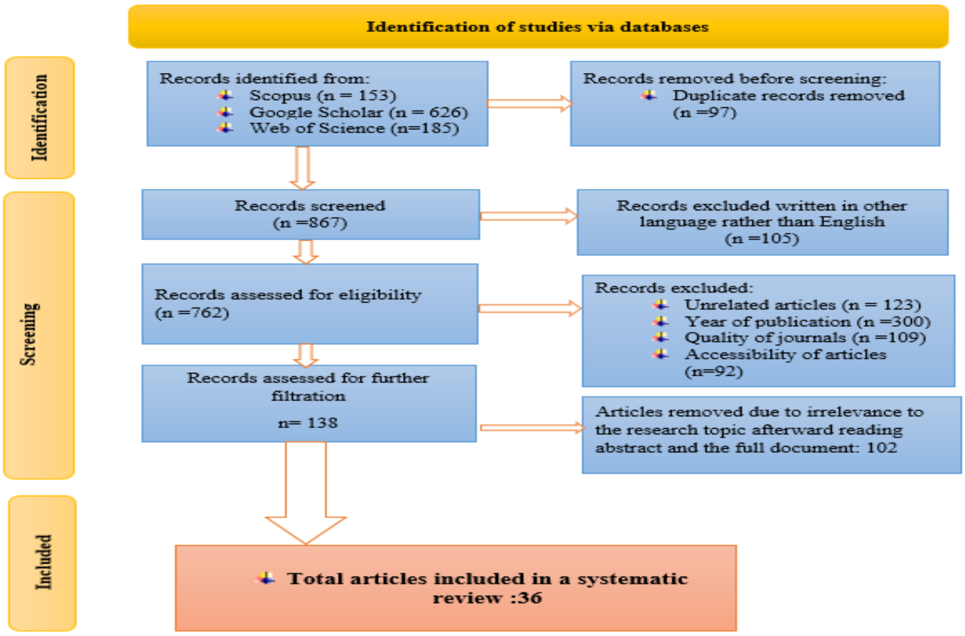

Fig 1. Steps to Selecting Articles for Review

Hence, to maintain the quality of the review, all duplicate publications were thoroughly checked to remove them. Abstracts of the articles were also thoroughly reviewed for analysis and purification to ensure the quality of the articles and related academic literature included in the review process. A careful evaluation of each research article was carried out later.

The following exclusion criteria were to limit the number of articles published in English only. A total of 105 articles published in the non-English language and 123 articles retrieved from other than computer science domains were excluded from the study. Moreover, after the filtering of duplicate records, 97 more articles were also removed from the study. Then, after assessing each article based on the inclusion and exclusion criteria, 138 were selected for further evaluation. Therefore, after reading the abstract and the full article, 36 articles are selected for review. Fig. 2 shows the articles chosen for the review and analysis.

In this study we want to answer the following research questions

RQ1: What are the hindering challenges in migrating on-premise data centers of small and medium-scale enterprises to cloud data centers?

RQ2: What are the contributions and challenges of the current state of art virtual machine consolidation techniques for energy-efficient cloud services in data centers?

RQ3: What are the possibilities for using consolidation in containers to achieve the energy efficiency goals of the data centers?

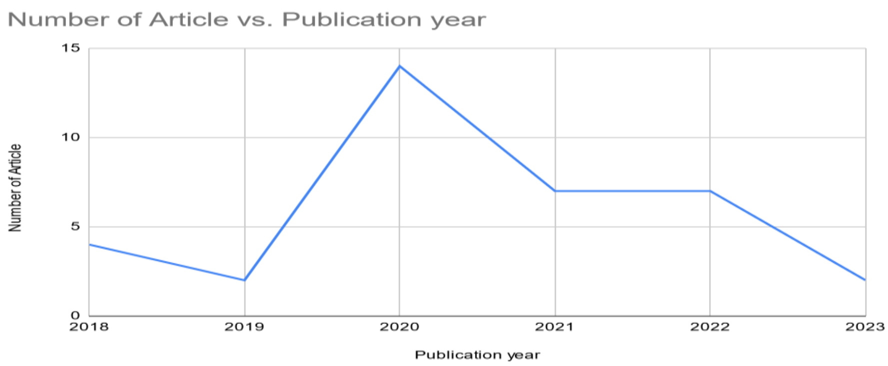

Fig 2. The yearly-based distribution of articles chosen for review

RESULTS

Regardless of the existence of small and medium-scale enterprises in different economy-class or developing countries, they have been facing challenges in migrating their systems from on-premise data centers to cloud data centers. After rigorously reviewing articles selected according to predefined quality metrics, different challenges were identified, as shown in Table 1. The summarized list of issues and challenges identified in the numerous studies are referenced in Service Consolidation and depicted in Fig. 3.

Table 1. Cloud Migration Challenges identified and critically analyzed from the selected literature

References	Issues and Challenges Identified in the numerous studies referenced in Service Consolidation	Country of target SMEs
[31]	Lack of standardized framework for adoption of cloud computing in SMEs of Indonesia	Indonesia
[32]	Lack of knowledge of migration process and cost-effectiveness, cloud readiness of legacy applications, migration complexities, data privacy, cost, interoperability, and lack of a unified framework.	Cross-country research
[33]	Lack of control, Privilege Abuse, Limited Customization, Unpredictable Performance, Difficulty in Integration, Vendor Lock-In.	Malaysia
[34]	Scarcity of finance and technology capacity in the countries', Lack of Government intervention,	Cross country study
[35]	Lack of trust in cloud service providers may also increase risk perception. Ensuring security and privacy and building trust among the involved parties are the significant challenges for cloud	Bangladesh
[36]	Security and privacy issues were some of the key inhibitors to cloud computing adoption among SMEs.	SMEs in developing economies
[37]	High latency rates, Trust, data privacy and security, Data Governance Construction, Poor broadband connectivity of construction sites, Access, Cost implications of long-term use accumulation, High chances for scoring dark data, Threats of edge computing and other associated technologies,	Cross country study
[38]	Technological (i.e., complexity and security) and organizational (i.e., top management support and prior IT experience) factors positively affect adoption.	Lebanon
[39]	Application interdependence and data integrity during cloud migration process in SMEs	Cross country study
[40]	Size of data, regulatory considerations, business applications' cloud readiness, cost of downtime and SLA requirements, and application and data migration in case of change in a cloud provider.	Cross-country study
[41]	Several technological, human, security, and financial factors are involved in the decision-making process to move to the Cloud.	Cross country study
[42]	Security, privacy, and interoperability of data and systems, the lack of technical knowledge of the staff, the inertia and organizational culture	Cross country study
[43]	Data locality and security, Network, and web application security, Data integrity, and identity management	India
[44]	Technical factories such as relative advantage, perceived ease of use, and perceived usefulness. Top management support and technology readiness as organizational factors. Regulatory support and trust in the vendor are external factors.	Southland, New Zealand
[45]	Legal and regulatory issues, Internet connectivity issues, reliability of the services, compliance with rules and regulations, and interoperability were mentioned as challenges for startups.	Indonesia
[46]	The trust in the cloud service provider, the approach of CSP, the reputation of CSP, and the quality of cloud services.	Cross country
[47]	Lack of reliable Internet connections, lack of trust in QoS, lack of in-house cloud experts, loss of control, and legal issues were revealed as barriers to cloud adoption in SMEs.	Ecuador
[48]	Organizational factors (top management commitment, employees' attitudes, and right skills), environmental factors (industry competition and trading partner pressure), technological factors (perceived benefits, complexity, and compatibility), risk factors (policy and organizational risks,	Kenya

	technical risks; and legal risks);	

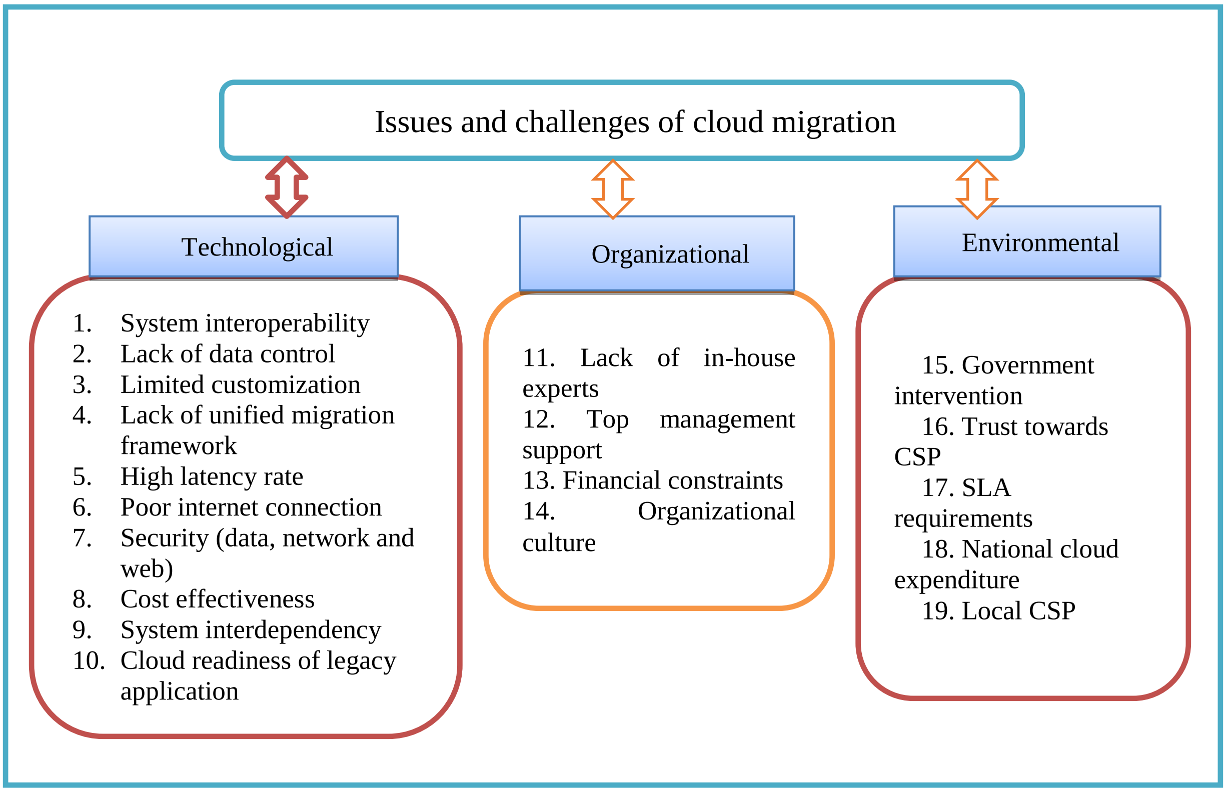

Fig. 3 Issues and challenges identified from the references

Table 2 summarize the contributions and limitations in VM consolidation algorithms and techniques for ensuring energy efficiency in resource utilization. Various algorithms and techniques employed in VM consolidations are rigorously reviewed to know how they help in optimizing the energy efficiency of the systems.

Table 2. Contributions and limitations in VM Consolidation Algorithms

Author(s)	Main Contributions	Limitations	Algorithm category
[18]	The proposed energy and SLA-aware VM placement (ESVMP) consumes less energy than other standard policies.	To achieve greenness, only the CPU Power consumption was considered. The impact of several VM migrations was missed/overlooked.	Online Algorithm
[49]	The proposed Energy Efficiency Heuristic with Virtual Machine Consolidation (EEHVMC) algorithm reduces power consumption while reducing SLA violations.	The power consumption of the CPU and the size of the memory of servers were considered in the proposed algorithm.	Online Algorithm
[50]	Proposed algorithms (PVMCA) tried to maximize the potential utilization of a minimum number of physical machines while attempting to allocate a maximum number of tasks to the active physical devices.	CPU was considered the sole factor to be taken into account when it comes to VM consolidation.	Online Algorithm
[15]	The proposed NVMC approach outperforms other well-known methods/approaches by achieving a significant improvement in	CPU, memory, bandwidth, and storage resources were considered for VM	Online Algorithm

	energy consumption, SLA violations, and the number of VM migrations.	placement.	
[51]	The proposed solution maximizes the energy efficiency of the data center and reduces SLA violations by optimizing the multiple resources of the system.	The CPU level of utilization was considered for power consumption.	Online Algorithm
[17]	The recommended model effectively manages the resources on the servers by minimizing the number of active servers and ultimately minimizing the overall energy consumption.	The VM selection and allocation criteria were not mentioned. The SLA was not considered in the proposed algorithm. The number of PMs, VMs, and tasks was not sufficient.	Meta-heuristic algorithm
[52]	The proposed VM placement algorithm provides better performance than that of the benchmark algorithm PABFD in terms of energy efficiency, SLA, the number of host shutdowns, and VM migrations.	The power consumption of the CPU was the only variable considered for energy efficiency. It doesn't guarantee an optimal solution. The result wasn't clearly reported.	Meta-heuristic algorithm
[53]	The results show that the proposed approach decreases energy consumption when compared to approaches in the current state of the art. This improvement comes with some SLA violations.	The static threshold coefficient to check under and overutilization was not mentioned clearly. CPU utilization was the only parameter for VM consolidation.	ML approach (Regression analysis)
[54]	DTMC model for PM status prediction and then used along with the CTMC model was exploited from the previous work. These models made it possible for more efficient PM categorization. The proposed algorithm performs better than other bench algorithms.	Only the power consumption of the CPU was considered under the proposed algorithm.	Meta-heuristic algorithm.
[19]	The results of the simulations demonstrate that the proposed model (ML-MUC- MBFD) decreases energy consumption by 26%, SLAVs by 50%, ESV by 60%, and the number of VM migrations in the data center by 86%, all in comparison with a baseline model (LR-MMT-PBFD).	CPU utilization, memory size, and bandwidth were variables/resources considered in the proposed algorithm. The total number of PMs used for the simulation was not mentioned	Machine Learning
[20]	The proposed approach significantly reduces the SLA violation rate and the number of migrations, with an appropriate balance between energy consumption and perfect execution times compared to the existing benchmark algorithms.	The power consumption of the CPU of the host machine was the only parameter considered by the prediction algorithm.	Machine learning algorithms have
[55]	The results of the proposed algorithm reveal that the K-medoids algorithm is more effective than K-means, and four thresholds result in saving a more significant number of hosts as compared to three points of thresholds. Considering other factors, such as bandwidth, in addition to CPU utilization, is more effective.	It considers bandwidth in addition to CPU utilization and memory. but not the power consumed by memory or networking devices.	Online Algorithm

[56]	A CPU-Memory aware VM placement algorithm was proposed that considers three variations of resource utilization: Memory, Ratio of CPU to memory utilization (RCM), and Product of CPU and memory (PCM) utilization. They were giving competitive results in generating quality service during VM consolidation.	Computation overhead.	Heuristic Algorithm online algorithm

A comparative analysis of VM selection and placement algorithms is depicted in Table 3, i.e., how various researchers check the underload or overload status of the hosts by considering the experimentation or simulation using evaluation metrics.

Table 3. Comparative analysis of VM Selection and Placement Algorithms

Author (s)	Host Overload/ Underload Detection	VM Selection	VM Placement policy	Evaluation metrics
[18]	IQR (InterQuartile Range)	MC (maximum correlation)	ESVMP (Energy SLA Aware VM Placement)	Number of migrations, SLAV, Energy consumption, ESLAV.
[49]	Dynamic threshold (T_{high}, T_{low}) The InterQuartile range was used for threshold setting.	MRCU (Maximum ratio of CPU utilization to memory utilization)	MRCU (Maximum ratio of CPU utilization to memory utilization)	SLAV, power consumption
[50]	Dynamic Threshold by Linear Regression	Maximum Power Reduction Policy (MRP) Select VM, which minimizes the PM power utilization. Time and power trade-off policy (TPT)	VM Proposed Placement Algorithm (VMPPA)	Vitality utilization, ECSLAV, SLATAH, PDM, and SLA violation.
[15]	The overloaded host is retrieved based on the weight of the resource requested. The algorithm then returns the host with the minimum CATR value.	NVMC	The host with the minimum CDTR value.	Power consumption, SLAV, and number of VM migrations.
[51]	IQR &MAD	High power (HP) consumption VMs	The net increase in Imbalance Utilization Value (IUV) and power consumption of a PM.	Power consumption, SLAV, ESV, number of VM migrations
[17]	Threshold value	Not mentioned	Adaptive beetle swarm optimization (ABSO)	Energy consumption, memory utilization, migration cost
[52]	Local regression	MMT	Particle Swarm Optimization	consumed energy, number of VM migrations, number of host shutdowns and the ESV
[53]	Static Threshold	Static- Threshold	Static Threshold (Maximum resource utilization by the host)	Energy consumption, SLA violation, and computation time.

[54]	DTMC and CTMC	Based on the expected finishing time of tasks running on specific VMs on a given host, The CPU utilization before and after the selected VM migration. Or the migration time of VMs from source to destination	MOABC	Energy consumption, resource wastage, and system reliability to meet SLA and QoS requirements.
[19]	CPU utilization of VM to identify overloaded PM and CPU level of utilization of PM to identify underutilized host machine	A VM with the maximum predicted CPU utilization was selected for migration.	MBFD. Sort in descending order of next time CPU utilization in the list of VMs in migration and allocate to hosts with high CPU utilization after allocation.	Energy consumption, SLAV, SLATAH, PDM, and ESV
[20]	Based on K-SVR predicted current and future host CPU utilization thresholds,	MMT	PABFD	SLV, Energy consumption, number of migrations, execution time
[55]	Adaptive Threshold	Maximum Ratio of CPU to Product of Memory and Bandwidth (MRCPMB), Minimum Product of CPU, Bandwidth, and Memory (MPCBM) for CPU and Memory, respectively	Energy-efficient VM placement algorithm that minimizes both energy efficiency and SLA at the same time.	Energy consumption, SLAV, ESV, and number of VM migrations.
[56]	Adaptive Threshold. K-Means InterQuartile Range clustering algorithm. Which clusters the host into 5 groups	A Fuzzy Soft Set (FSS) based VM Selection algorithm.	CPU-Memory aware VM placement algorithm	Energy consumption, SLAV, ESV, and a number of VM migrations.

In addition, the Fig. 4 shows the energy consumption of data centers in simulated environments reported by different researchers. The X-axis shows VM consolidation algorithms proposed by respective authors while the Y-axis shows the energy consumption in kilowatt-hours (KWH). In this Fig 4; researchers reported that the proposed VM consolidation algorithms were found better than benchmark algorithms but the graph reveals inconsistent growth.

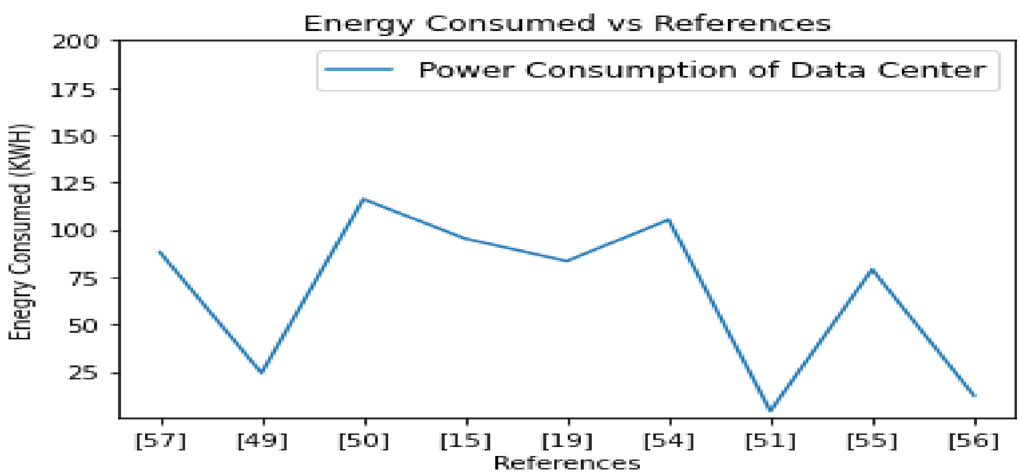

Figure 4. Total energy consumption in KWH

Figs. 5 and 6 depict the status of the total VM Migration and violations, respectively, by the numerous research studies to check the above-mentioned energy efficiency parameter. In order to minimize the power consumption of PMs migrating one or more VMs running on underloaded PMs, converting overloaded hosts to medium-loaded hosts is required. When the number of VM migrations increases, it may violate the green premises in the SLA because the power consumption will be significantly increased. This implies that to achieve the desired increase in energy efficiency in algorithms; the number of PMs should be significantly high.

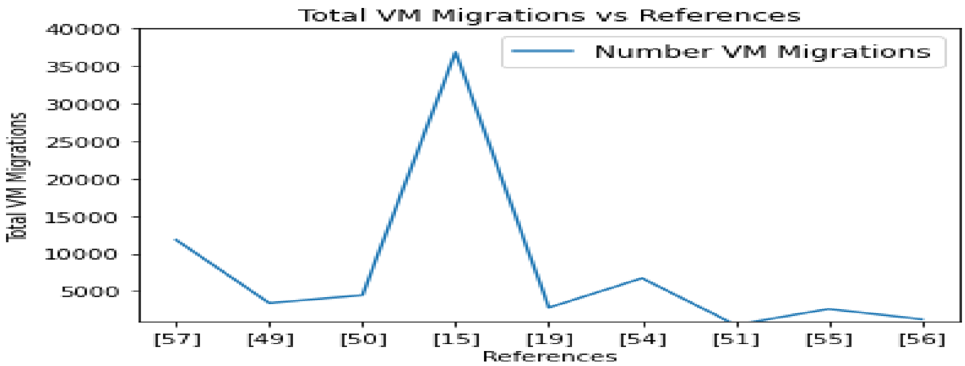

Figure 5. Total number of VM Migration

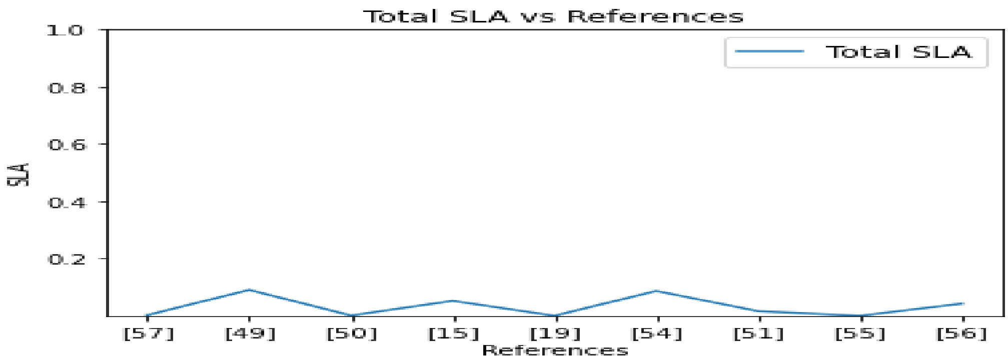

Figure 6. The total number of SLA violations

Containerization is a powerful technique for deploying applications, particularly beneficial for small and medium-sized enterprises (SMEs). It enhances the portability, scalability, and security of business applications, making it a good option for improving energy efficiency. This is because containers encapsulate applications and their dependencies into isolated units, which can run consistently across different computing environments.

Table 4. Summary of Container consolidation approaches

Reference(s)	Objective (s)	Virtualization technique	Experiment	Contribution	Potential Gaps
[58]	Minimize the power consumption of the data center.	VM and the containers	CloudSim	The algorithm minimizes energy consumption and execution time.	Inter-container communication and other related QoS were overlooked.
[59]	Power consumption and resource utilization (CPU and memory)	VM and Containers	CloudSim	The proposed container placement algorithm searches for a suitable number of VMs and PMs as a single problem. The algorithms reduce the number of PMs by nearly 50% compared	The proposed algorithm failed to include other QoS parameters, such as energy efficiency

				to the initial number of PMs.	
[60]	Minimizing power consumption	Containers	Simulated the scenario by Python script	The proposed algorithm, 'Energy-Aware Service Consolidation using Bayesian Optimization (EASY),' employs a statistical online learning technique with Bayesian Optimization (BO). The study found that EASY outperforms other algorithms in total energy consumption while maintaining service quality (QoE).	The proposed algorithm's response time is higher than another benchmark algorithm. The service time is increased by the service provider may break the compliance of SLA, and hence it needs remedial provisions.
[61]	Minimizing power consumption and SLA violations	VM and Containers	CloudSim	Experiments demonstrated that the container consolidation scheme using usage prediction achieved significant improvements. It reduced power consumption, minimized the number of container migrations, and lowered the average number of active virtual machines, all while ensuring adherence to service level agreements (SLAs).	The proposed scheduling algorithms didn't consider inter-container communications costs.
[25]	Maximize the resource utilization	VMs and containers	Simulated in MATLAB	This study introduces scheduling and placement algorithms to optimize container and virtual machine (VM) allocation, aiming to maximize resource utilization for both physical machines (PMs) and VMs. The evaluation shows that their Ant Colony Optimization (ACO) approach is highly effective, excelling in maximizing VM and PM utilization while minimizing the number of active PMs and deployed VMs. However, ACO may initially activate more PMs, as it prioritizes	The proposed scheduling algorithms were unable to manage dependent workloads effectively. Additionally, incorporating extra computing resources, such as processing cores, memory, storage, and data transfer bandwidth, is necessary for improved results. Furthermore, the algorithm did not take into account service level agreement violations.

				using the least powerful configurations that meet resource requirements, potentially increasing the number of active PMs slightly.	

DISCUSSION

Businesses that have adopted cloud computing have experienced numerous advantages. Studies show that cost savings, due to reduced upfront costs, are the most recognized benefit. Additionally, cloud computing improves internal processes, leading to faster decision-making, expanded markets, and improved customer communication and satisfaction [28].

When enterprises plan and migrate their business processes to the cloud, it creates an opportunity to cut hardware and software costs. As a result, cloud service providers automatically take care of issues with upgrading and maintaining the hardware and software. Adopting cloud computing technology to support the business activities of SMEs changes the CAPEX model into an OPEX model as another cost advantage for enterprises [22]. Enterprises migrated to a cloud environment can utilize the best features, such as high scalability, cost-saving solutions, updated and standardized security features, the opportunity to manage incomings and outgoings (easy to manage income and expenses), the opportunity to develop new skill sets, and organizational development opportunities [29].

Although cloud computing offers significant benefits to small and medium-sized enterprises (SMEs) by enhancing their business processes and operations, many studies indicate that SMEs still encounter numerous challenges when migrating their systems to cloud environments. These challenges include data integrity and security, business continuity during migration, cost overruns due to inadequate cloud planning, and the adaptability and portability of applications. When assets are transitioned from legacy infrastructure to the cloud, these issues require rigorous study, analysis, and redesign.

Unfortunately, many studies in the domain have not sufficiently focused on these challenges. As depicted Fig 3. critical issues such as affordability, on-demand scalability, high reliability, and energy efficiency remain underexplored. These factors are particularly important in the context of SMEs in developing countries, such as Ethiopia, and warrant further research efforts in these specific areas.

Virtual machine (VM) consolidation techniques have proven effective in reducing energy consumption in data centers. However, several challenges remain. One major challenge is the need for more accurate VM resource utilization prediction models. Another is the necessity of considering VM heterogeneity during consolidation.

To minimize power consumption, it is essential to migrate VMs from underloaded physical machines (PMs) and convert overloaded hosts to medium-loaded hosts. However, an increase in the number of VM migrations can significantly boost power consumption, potentially violating the green premises in the service level agreement (SLA). This suggests that to achieve the desired increase in energy efficiency, the number of PMs should be sufficiently high.

After a rigorous review of existing research, it is evident that the number of VMs and PMs needs to be explicitly mentioned to further validate the proposed results. As mention in Table 4. the performance of the proposed algorithms was validated in a simulated environment with a single workload dataset, which is difficult to generalize the overall performance of consolidation. Additionally, the time interval for committing VM migrations and the span of tasks running on VMs during migration were not explored.

Most studies focused on the energy consumption of CPUs, as depicted in Table 2. neglecting the power consumption of other data center resources such as memory modules, storage devices, I/O devices, networking devices, and cooling systems as well as green software design artifacts should be considered. These factors should be considered when designing enhanced energy-efficient consolidation algorithms.

CONCLUSIONS

Cloud computing is an emerging technology that supports the business processes of organizations to enhance the quality of service and customer satisfaction. Most of the researchers discussed only four major cloud migration strategies, namely, complete migration, mixed migration, component replacement, and cloud-enabled migration. Based on the organization's business strategy and other criteria, the services can be migrated to public, private, community, or hybrid cloud deployment models such as IaaS, PaaS, SaaS, or XaaS types of service models, as the organization may prefer. Since small and medium-scale enterprises significantly contribute to the gross domestic product of any country. When organizations utilize cloud computing technology, they can minimize the capital expenditure of IT resources and operational costs. In addition to that, it enhances the quality of services like availability, scalability, security, energy efficiency, and agility for their ICT needs in the dynamic market trends. By giving workers freedom over where and when they work, cloud computing helps small and medium-sized businesses (SMEs) execute human resources management more effectively. This leads to better job planning and organization, which in turn boosts employee engagement and satisfaction. Additionally, by utilizing cloud computing services, small and medium-sized businesses (SMEs) can reduce their expenditures on IT infrastructure, which includes avoiding the need to hire experts, buy pricey hardware and software, secure data, and provide professional and technical support services. Cloud computing's many applications, scalability, and online accessibility have demonstrated that it is a solution that offers fresh perspectives and new avenues for managing small and medium-sized enterprises.

Despite the fact that cloud computing has numerous advantages, it necessitates careful and planned action. Cloud migration is a complex process with many challenges. These challenges can be divided into three categories: technological factors, organizational factors, and environmental factors. Before executing cloud migration projects, small and medium-sized businesses should consider those challenges. Unplanned cloud migration may cause more problems than it solves for businesses, and reverse migration will be not only time and cost-consuming but risky as well.

To deliver services on demand to cloud customers, cloud service providers establish redundant data centers with thousands of physical computing machines and network infrastructure to ensure high availability and fault tolerance. These cloud data center infrastructures and their cloud servers consume huge amounts of energy and contribute to global warming.

By lowering the number of active servers, cloud service providers can reduce data center power consumption and maximize server usage through the use of virtualization techniques. Virtualization and/or container consolidation are two methods to improve energy efficiency. This review study examines the many researchers proposed VM consolidation methodologies, including statistical, dynamic, and predictive approaches. In order to reduce SLA violations and maximize power use efficiency, the virtual machine consolidation option was selected. Despite this, there is a trade-off between SLA violations and energy efficiency.

The alternative virtualization technique utilized in on-premises or cloud data centers is containerization. Containers in the system that are energy-efficient, light weight, portable, and easy to deploy and migrate. Conversely, containers do not require a guest operating system or the host operating system and require container engines and runtimes in order to manage the life cycle of containers and resource requirements. However, public cloud service providers deliver containers as a service on top of the VM in order to utilize the best features of the two virtualization techniques. Whether containers are run over VM or/and PM, they demand computing resources (CPU, memory, bandwidth, and I/O) to run various applications. As a result, different researchers proposed different container consolidation techniques to achieve certain objectives, such as energy efficiency, minimizing SLA violations, and decreasing the response time. This paper can be used as a single source of compiled issues and challenges in the consolidation of VMs and containers to achieve energy efficiency in the data centers of SMEs. In the future, researchers can devise techniques to alleviate the aforementioned issues and challenges faced by the data centers of various organizations in general and small and medium-sized businesses in particular.

Credit author statement

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

This is a review article, and no underlying dataset was used to support this study.

Informed Consent

There were no human subjects.

Animal Subjects
There were no animal subjects.

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