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Challenges and Practices Identification via a Systematic Literature Review in the Adoption of Green Cloud Computing: Client's Side Approach

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ABSTRACT Green cloud computing gains popularity over the last decade due to the extensive use of cloud computing. The trend towards cloud computing is spreading at a fast rate. Cloud computing providers extend their data centers at regular intervals. However, cloud providers face severe issues about sustaining the environment because big data centers are responsible for consuming a vast amount of energy and producing a carbon footprint. The solution to address such an issue is green cloud computing. In the literature, a considerable amount of research has been done to determine the challenges and practices in adopting green cloud computing. Still, the field is immature and needs further research to identify the challenges and practices faced and addressed by various stakeholders. This research focuses on identifying the challenges faced by client organizations in adopting the green cloud and the associated practices for addressing the challenges. The challenges and patterns were identified via a systematic literature review from the relevant literature. After thorough conduction of the systematic literature review (SLR), we have identified 9 challenges and 63 practices from 68 papers in the cloud domain. In the future, we plan to develop a comprehensive framework by using some robust soft computing techniques like Fuzzy logic or AHP, etc., to assist the clients in adopting the green cloud environment.

INDEX TERMS Energy-efficient cloud computing, green cloud computing, challenges, practices, systematic literature review.

I. INTRODUCTION

Over the last decade, the concept of Green Cloud Computing (GCC) gains popularity due to the extensive usage of cloud computing. Further, cloud computing is widely in practice by many organizations worldwide for its easy accessibility and the provision of cheaper storage [1]. So, the extensive use of cloud computing is a reason for big data centers. These, in turn, have yielded many environmental problems such as carbon footprint, high energy consumption, and costly maintenance. The request for cloud computing is enhancing day by day [1]. Cloud computing providers are facing severe threats of how to sustain the environment. Consumption of more energy is directly proportional to more cost, and more importantly, has a critical impact on the environment [1]. To cope with environmental issues, the concept of GCC emerged. Using Computers and further advances in a highly effective manner will expand the utilization of assets, energy-efficient connected devices and lessening the waste of electronic devices. This approach is called Green Cloud Computing [2].

GCC is a successful method to limit energy utilization alongside energy management and infrastructure of computer operations [3].

GCC tries to reduce energy consumption and shrink the impression of carbon produced without impacting the organization's efficiency regarding security, maintenance, response time, etc., as provided by the cloud providers [3].

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Usually, data centers need significant reinforcement of power supply systems, numerous network links, cooling systems, and some relevant system security approaches for successfully running critical applications to an organization [4].

Processors, power supplies of servers, other server segments, capacity, and correspondence hardware represent practically 52% of the overall utilization of a server [4], [5].

The GCC aims to diminish the utilization of dangerous ingredients, increase energy efficiency, and strengthen the reusability process. GCC can be brought nearer from various perspectives navigating from hardware and software to legal, administrative, and executive problems [6], [7].

That is why green IT advancement has become imperative in data centers [4], [8], whereas some of the critical benefits of the green cloud are as follow:

- To decrease the number of vitality bills.
- To sustain and increase business productivity.
- Optimal usage of equipment assets with broadened valuable life/to increase the life cycle of the equipment.
- To reduce the downtime risks and maintenance requirements.
- To lessen the carbon footprint.

Despite the benefits mentioned earlier of green cloud computing, GCC has many challenges. Many researchers have found the generic challenges and practices for the GCC. Some of these challenges in GCC are as follow [3]:

- Dynamic resource allocation based on energy.
- Selection and provision of resources based on QoS.
- Virtual-Network-Topologies Optimization.
- Autonomous optimization of the thermal condition and the freezing operation of a device.
- Efficient heterogeneous workload management aggregation of VMs.

Although much work has been done to identify challenges and their practices in GCC [3], however, they mainly focused on the general perspective. Likewise, from the vendor's perspective, a literature review on adopting green-cloud features and the vendor's actual implementation has been published [2]. There is no such particular work done from the client's perspective. We will focus on the client's perspective. That is why we are doing this research to find out the challenges and practices confronted by clients in the adoption of GCC.

We specifically focus on this topic because clients are an essential pillar of any organization. Businesses, one way or another, rely heavily on clients. To ensure green cloud computing to be successful, we need to find out the challenges clients face in the adoption of GCC and identify the possible solutions/practices to these problems.

To achieve the objectives mentioned above, we have formulated the following research questions (RQs) for this SLR:

RQ1. As identified in the literature, what are the challenges confronted to clients in the adoption of GCC?

RQ1.1. Do these challenges in adopting GCC may vary with time?

RQ1.2. How are these challenges related to the study strategies used in the literature?

RQ1.3. Do these challenges in adopting GCC may vary concerning publication venue?

RQ2. As identified in the literature, what are the practices/solutions for addressing the identified challenges for clients in the adoption of GCC?

The rest is organized in the following manner: Section-II provides the background about software security. Section-III presents detail about the research methodology. The outcomes from the applied SLR are present in Section-IV. While, the limitations of the study are provided in Section-V, followed by the conclusion and future work presented in Section-VI, respectively. The rest of the sections provides additional materials.

II. BACKGROUND

From the classical to the modern era, the computing industry has evolved rapidly than any other field of science. It is also to be noted that from classical to today's modern era, the variation has been made possible by the use of evolving computers. Every field of science relies directly or indirectly on computers. To catch up with the increasing demand, the computer industry has been expanding rapidly, which harms the environment. We cannot diminish the growth of computer systems from expanding because we need them to fulfill our needs. Therefore, we need a solution to the issue at hand. Over the last decade, extensive research has been done in the computer industry to make green cloud computing sustainable. Some of the significant work done is as follows.

Kaur and Kinger [9] cloud computing (CC) combined with energy-efficient computing is called GCC. Data centers are used to maintain data for the CC. CC is expanding both in industrial and academic infrastructure. That is why most companies and businesses adopt CC to ensure that the relevant data is secure, leading to raising large data centers.

Large type data centers will ultimately need a massive total of electric power. More power in data centers will cause more carbon footprint, and as a consequence, it will drastically affect the environment.

Kaur *et al.* [10], to overcome energy consumption and CO2 emissions, it is imperative for cloud computing to develop aware thermal mechanisms and save energy for resources to be used efficiently.

Farahnakian *et al.* [11] proposed VM merging to diminish the energy consumption for the data centers based on VM live migration without affecting the QoS. However, it did not consider green energy and focuses on energy optimization.

Deng *et al.* [12] proposed an eco-aware optimization of energy and load scheduling for data centers using an online algorithm. Using Lyapunov optimization theory, the optimization problem is obtained and handled. Then, proposed an online control algorithm to meet tasks' performance requirement while attaining the minimization of the eco-aware energy cost of data centers. Furthermore, a stochastic type optimization issue is obtained as well tackled via the theory of Lyapunov optimization. However, it gives attention to leveraging the eco-aware supply cost for a long time. Nguyen and Cheriet [13] introduced a method for environmental awareness with virtual slices to address uplifting energy inconsistency. To efficiently diminish the footprint for the environment, a virtual slice allocation problem is planned and addressed that takes into account the uplifting energy supply, locations for VM, and bandwidth for the network.

Hasan *et al.* [14] adopt renewable energy virtualization technologies to solve the supply uncertainty issue in data centers. Owing to uplifting energy's obtainability and erratic presence, a green-SLA algorithm was proposed for data centers.

Qiu *et al.* [15] proposed an algorithm of genetic-based chip-multiprocessors with phase shift memory for green-cloud computing. It achieves a balance between memory utilization efficiency and overall execution time by allocating tasks to cores. However, it optimizes memory use and ignores the use of renewable energy to reduce energy consumption.

Kiani and Ansari [16] proposed a unique workload delivery system for the geographically disseminated green data centers to optimize benefits. A G/D/1 queue was used for modelling and testing the outcomes of data centers. Various electric charges and the SLAs in disseminated data centers were used to formulate a convex optimization problem.

Hassan *et al.* [17] presented a new as a well-efficient method for attaining price-effective resource distribution in a cloud federation. Furthermore, the interactions amongst the cloud providers inside a federation were modelled as an alliance game in the process with the goal in mind to maximize the full benefit and the social welfares of cloud providers. In addition, a detailed overview of cloud providers' income and prices upon entering a federation was provided.

The focus of this study is to shelter almost all the relevant literature to find out challenges faced by clients in the adoption of GCC. In addition to finding out practices for the identified challenges.

III. RESEARCH METHODOLOGY

To collect data from the existing research, we have accomplished the SLR. The reason behind conducting the SLR is that it is more thorough than an ordinary- literature review (OLR). Furthermore, SLR is based on preconceived protocol [18], [19]. SLR consists of three main stages: planning a review, conducting a review, and reporting a review. The objectives of these stages are to find, categorize, and interpret all the available resources based on their evidence strength. It enables the research community to transfer knowledge among themselves [20].

A. SEARCH STRATEGY

A search was performed based on the keywords related to the specific topic. Keywords were composed to develop a search string that addressed the research question. The search string was then executed in different academic libraries and search engines.

1) SEARCH STRING

We have followed the guidelines for SLR by Kitchenham [19] and the further updates of Mendes *et al.* [21] for SLR to develop our SLR protocol. Furthermore, we have adopted PICO criteria (Population; Intervention; Comparison; and Outcomes) to identify keywords and formulating the search strings from the research questions. Other researchers have used the same methodology [22].

Population: green cloud computing

Intervention: challenges, practices

Comparison: No comparisons take place for the current study.

Outcomes of relevance: Strengthening green cloud computing.

We have used the Boolean connectors and OR to connect PICO features for constructing the search string. ((''Energy-Aware cloud'' OR ''Energy-efficient cloud'' OR ''Green cloud'') AND (''Cloud Computing'' OR ''Green Cloud Computing'') AND (''challenges'' OR ''barriers'' OR ''risks'' OR ''practices'' OR ''solutions'' OR ''clients'' OR ''user''))

2) LITERATURE RESOURCES

We searched for libraries such as Springer Link, IEEE Xplore, ACM, and Science Direct using our constructed search string. The search string results in different libraries are present in Table 1.

B. CRITERIA FOR STUDY SELECTION

The researchers encouraged the strings [23] and the authors' suggestions. Initially, we added the string to the metadata of libraries. The same was performed with care in mind of not disturbing the title, the abstract, and the keyword constraints. Each paper was retrieved and documented in a detailed manner with keeping its complete record by the first author. Based on such a step, other authors reviewed the articles by assigning the relevant pieces of information of each article, such as title and abstract.

Following the guidelines above for the SLR conduction, we have set the following inclusion and exclusion criteria below [19], [21].

1) INCLUSION CRITERIA

- IC1: Full-text article in the English language.
- IC2: Sources that are relevant to GCC.
- IC3: Sources that focus on GCC challenges.
- IC4: Sources that focus on GCC practices.
  IC5: Journal and conference papers, standards and white papers, and reports published by reputable organizations.

2) EXCLUSION CRITERIA

- EC1: Studies that are not related to our research questions.
- EC2: Papers other than the English language.

TABLE 1. Search string outcombes per database.

Search String	Digital-Libraries	Total Results	Initial Selection	Final Selection
(("Energy-Aware cloud" OR "Energy-efficient cloud" OR "Green cloud") AND ("Cloud Computing" OR "Green Cloud Computing") AND ("challenges" OR "barriers" OR "risks" OR "practices" OR "solutions" OR "clients" OR "user"))	IEEE Xplore	362	59	33
	Science Direct	217	20	18
	ACM	91	12	04
	Springer Link	509	29	13
Total		1,179	120	68

TABLE 2. Assessment of quality for publications.

ID	Quality-Assessment-Criterion	Answer
Q1	Does the paper provide well-defined aims and objectives?	Yes/no/partially
Q2	Does the article have a clear context, e.g., industry or laboratory setting?	Yes/no/partially
Q3	Does the paper explicitly discuss the limitations?	Yes/no/partially
Q4	Does the paper add challenges for clients in GCC?	Yes/no/partially
Q5	Does the paper add practices for clients in GCC?	Yes/no/partially

- EC3: Papers with workshop summaries.
- EC4: Duplicate sources
- EC5: Books, web pages, and magazine articles.

Table 1 depicts the summarized results for the search process. Based on the inclusion criteria, we have extracted 283 papers from 1,179 papers. Then by applying the exclusion criteria, we finally selected 68 papers. The finally selected papers' IDs and titles are listed in Appendix-A. The primary author performed each step of the data extraction process, which was then rigorously reviewed by secondary authors.

C. QUALITY ASSESSMENT

We assessed the primary studies reviewed based on the publication results and the answers to our research questions [19]. We design our quality assessment criteria from a few selected studies [20], [24]–[26]. The questions of the quality criteria are present in Table 2. To grade each question of the reviewed studies for quality assessment criteria, we used a three-tier scale. i.e., *Yes, Partially, or No*. To yield measurable outcomes, we assigned the values as 2 → Yes, 1 → partially, and 0 → No.

Further, we only included the paper on the condition if it secured an average score of _ 0.5. During such a process, the first author was responsible for applying the quality assessment parameters to the articles, whereas the other authors validated the similar assessments up to a slighter set of arbitrarily selected studies. Based on such quality criteria, the secondary reviewer excluded six papers. Any differences were fixed through deliberations. The main aim of the quality assessment was to exclude low-quality studies and designate the integrity of the findings of a study [20], [24].

D. EXTRACTION AND SYNTHESIS OF DATA

From the total 68 selected articles, we extracted the below data from each as:

- Paper-ids and Paper Titles (see Appendix A)
- Publication Channel (see Appendix B)
- Year of Publication (see Appendix B)
- Research Methodology (see Appendix B)

IV. RESULTS AND DISCUSSION

In this research, we focus on finding barriers/challenges faced by clients in the adoption of GCC. We also focus on providing the clients appropriate solutions/practices to mitigate those barriers/challenges. The details of our findings are given in sections IV.1 and IV.V.

A. CHALLENGES FACED BY THE CLIENT's ORGANIZATIONS IN THE ADOPTION OF GREEN CLOUD COMPUTING

Here, the study has dug out nine critical challenges the clients face in adopting green-cloud computing, as shown in Table 3.

CC #1 Lack of Quality of Service: The satisfaction of quality-of-service (QoS) requirement is one of the biggest challenges the client's organizations face in adopting green cloud computing [27].

In a firmly joined VM, where once high demand is put on any submission, the performance can suffer. Since customers value QoS so highly, there is a tradeoff between energy consumption and computational efficiency that must be carefully considered [28].

CC#2 Lack of Dynamic Response: The technology behind Dynamic-Power-Management is focusing on conserving energy by switching off the computer Servers. For example, in the data center, one can save a lot of energy by switching off the non-functional servers. On the other hand, continuous turning on and off a server can cause a time delay [29].

CC#3 Lack of Services to Address Client's Specific Requirements: The demand for applications fluctuates a lot and by a large margin. Even if automated techniques are used, dramatic load increases can occur at such a pace that new types of VM instances cannot boot fast enough to meet the response time supplies [30].

CC#4 High Cost: Cloud computing that is environmentally friendly having problems with computation infrastructures

TABLE 3. Challenges in adopting the green-cloud computing.

S. No	Challenges	Paper ID	Frequency
1	Lack Of quality of service	2,3,6,8,9,11,12,13,14,15,16,17,19,20,24,25,27,28,31,32,33,35,37,38,39,42,45,46,47,49,50,51,52,53,54,55,56,57,58,59,60,61,62,64,65,67,68	47
2	Lack of dynamic response	2,7,12,19,31,32,37,39,40,47,48,50	12
3	Lack of services to address client's specific requirements	2,4,5,6,10,11,12,19,31,39,40,53,60	13
4	High cost	2,4,5,6,9,10,11,12,13,14,16,17,18,19,20,21,23,24,26,28,29,30,34,35,39,41,44,45,46,49,51,57,58,60,63	35
5	SLA Violation	2,3,4,5,8,11,12,13,16,19,20,24,25,33,35,37,42,43,44,47,48,49,50,51,52,53,54,55,56,57,58,59,60,65,66,67,68	37
6	Lack of efficient provision of resources and services	2,5,6,8,10,12,13,14,15,16,19,21,23,26,29,31,34,35,36,37,39,41,44,45,46,48,50,52,53,55,58,60,62,63,64,66,68	37
7	Lack of Green and sustainable infrastructures for the provision of reliable and cheaper services	3,4,5,6,8,9,11,12,13,16,20,21,22,23,27,28,29,30,38,39,41,44,45,47,49,50,51,52,53,58,60,62	32
8	Lack of cybersecurity	9,13,14,18,22,35,43,46,47,50,51,60	12
9	Complexity in understanding cloud systems	2,5,17,21,22,23,28,29,31,35,38,43,50	13

TABLE 4. Practices for addressing Lack of quality of service.

CC #1 Lack of service quality or quality-of-service (QoS)		
S.NO	Practices to address the Lack of service quality	Frequency
CCP#1.1	The usage of a fuzzy controller (fuzzy-Q&E) can be allocated to VMs up to the least total physical capacity required to fulfill the QoS needs of the fuzzy controller.	7
CCP#1.2	The utilization of continuously unites VM's leveraging living migration and turning off the idle states nodes to lower the energy consumption, and at the same time the provision of the needed service quality.	7
CCP#1.3	The customer should explicitly describe in the Service Level Agreements (SLA) the potential latency between the services and the data transference conditions.	3
CCP#1.4	Before the agreement being signed and the data handed over the stage, negotiation of requirements are needed.	3
CCP#1.5	Usage of Energy-based-Efficient-Resource-Scheduling-Framework .i.e. EBERSF, to assist the cloud users during the resource scheduling process to address the power as a parameter of service quality.	13
CCP#1.6	Usage energy-efficient decentralized architecture to manage the resources under a virtualized cloud-center to obtain good enough service quality and lower operating expenses.	10
CCP#1.7	Usage of an energy-efficient system, vGreen, for the scheduling of VMs throughout the several servers, is performed to improve the overall power consumption, the performance, and the balancing of power across the system.	8
CCP#1.8	The use of Green Cloud Scheduling Model such as the GCSM system accomplishes the energy efficacy. It lets the favourite QoS to the operators in the view of matric satisfaction of task deadline.	12
CCP#1.9	Usage of multi-population-genetic-algorithm, for example, MGA, provides the most excellent amalgamated service with a lower failure rate in terms of the predefined QoS measurement by the users in larger-scale issues.	5
CCP#1.10	Use of a scheduling algorithm, for example, MinDelay, which accommodates the service demands in a cloud system by keeping in view both the client QoS supplies and the provider's profit.	5

that can not only reduce energy consumption but also make Cloud services secure and cost-effective [31]. Users of the cloud expect to pay the least amount of money for the services they rent [32].

CC#5 SLA Violation: Violation of the SLA is a critical problem because it causes cloud users to become frustrated, and their level of satisfaction gradually decreases [32]. Demand volatility could result in a service level agreement (SLA) breach and build-up of elasticity debt [33].

CC#6 Lack of Efficient Provision of Resources and Services: IT service providers are concerned with providing reliable services to consumers [34]. The successful use of VM- Scheduling and Resource-Allocation for power efficacy still faces many challenges, mainly by the performance influence imposed on the customer while migrating or provisioning VMs [28].

CC#7 Lack of Green and Sustainable Infrastructures for the Provision of Reliable and Cheaper Services: We anticipate that a growing number of clients will demand assurances that their workloads are completed using unique fractions of green energy, especially if they are required to do so by law [35]. As a result, modelling vulnerabilities can be considered one of the causes of energy usage because the model or service dupes the consumer that the provider claims to offer [36].

CC#8 Lack of Cybersecurity: Likewise, the performance of this green-cloud computing architecture, likewise most virtualization-based-cloud systems that run in a multi-type tenant cloud-environment, is heavily reliant on its security assurance mechanisms [37]. The cloud data center operator's primary concern during the VM migration process is the security of the migrating VM's contents, as the VM must

TABLE 5. Practices for addressing Lack of dynamic response.

CC#2 Lacks of Dynamic Response.		
S.NO.	Practices for addressing Lack of Dynamic Response	Frequency
CCP#2.1	Cloud elasticity allows the dynamic acquisition and release of public computational resources on request. Furthermore, one of the main advantages is the decision taking adapt to regulate the constraints of resource provided by the QoS and the operating prices.	9
CCP#2.2	Software-Defined-Networking .i.e. SDN, enables the centralized management of network switches and their traffic management via a programmable centralized controller. Such newly emergent technology can advance the QoS and energy efficacy in a cloud network center by proficiently performing the dynamic bandwidth provision per flow, the practical network virtualization alongside the traffic management with consolidation.	4
CCP#2.3	The virtual power plant, for example, VPP, maximizes the value of both the end-user and the dispersal utility by using a collection of software-based dynamic schemes to provide the value in real-time, and it can also react fast while changing the client load conditions.	1
CCP#2.4	Use of task scheduling using Clonal Selection Algorithm such as TSCSA is a collection of Pareto resolutions. It provides an extensive range of choices to select the most satisfactory solution based on the user's degree of preference specific goal dynamically.	2

TABLE 6. Practices for addressing Lack of services on the client's specific requirements.

CC#3 Lack of Services for Addressing the Client's Specific Requirements		
S.NO.	Practices for Addressing Lack of Services on the Client's Specific Requirements	Frequency
CCP#3.1	Use of Green Cloud model that is elastic enough in providing the right level of services needed by the client, and is simple up to the extent to motivate an extensive range of clients from various sectors.	7
CCP#3.2	The dynamic-voltage-and-frequency-scaling .i.e. DVFS, enables the processing elements to function at various power consumption stages for working at efficient task provisions (to the specified processing elements) based on user needs.	8
CCP#3.3	Virtual machines provide solutions to reduce the hardware needs to deliver services.	6
CCP#3.4	Use of Smart Cloud Optimization for Resource Configuration Handling, .i.e. SCORCH, analyzes the CSP illustrations for feature modelling to identify the feature groups that satisfy a few or all of the features' needs of numerous applications.	8
CCP#3.5	Use of Dynamic Least Consuming Resource (DLCR) policy to maximize user satisfaction.	5
CCP#3.6	Use self-managing-autonomic-computing-systems that intend the clients to concentrate on 'what' rather than on 'how to accomplish the desired task.	2
CCP#3.7	Use of Green Cloud Scheduling Model system, for example, GCSM, helps attain the accurate task provisions within the schedule as per the user needs.	2

TABLE 7. Practices for addressing the high cost.

CC#4 High Cost		
S.NO.	Practices for Addressing the High Cost	Frequency
CCP#4.1	GRS-WS (Green Resource Management Workflow Scheduling) is a cost-effective mechanism that satisfies the bi-objective of lowering the power and carbon consumption.	5
CCP#4.2	Adopt a Swarm Optimization strategy that typically delivers an energy-efficient solution by lowering the available price with efficient tasks assignment.	8
CCP#4.3	Finding a cheaper power source is significantly essential. Furthermore, a new power sourcing-aware technology is helpful to save the dynamic price.	5
CCP#4.4	Use of spatial-task-scheduling-and-resource-optimization mechanism likewise STSRO can lower the total price for a DGCDC provider with the exploitation of spatial-diversity of ISP bandwidth alongside the power charges, while firmly meeting the delay bound restrictions of tasks across the overall applications.	1
CCP#4.5	Allocations of VMs to the applications on request, where the cloud- infrastructure users can pay the amount for the servers incrementally, instead of investing substantial upfront costs to buy the new servers.	1
CCP#4.6	Adopt CPN-based-Green-Cloud-Schedule, for example, CGCS, a unit of Green Sched to schedule the tasks for the priority adjudging or predicting of energy-efficient types of equipment per the deadline and budgeting constraints.	1

migrate over sensitive data- links. Hijacking a virtual machine throughout relocation allows intruders to gain admittance to the operating state of the kernel, data from accommodated submissions, and hardware conditions for malicious purposes [38].

CC#9 Complexity in Understanding Cloud Systems: Compared to SLAs, it is difficult to identify the root cause of service disturbances in a cloud atmosphere due to its complexity by nature [39].

B. ANALYSIS OF THE IDENTIFIED CHALLENGES IN GREEN CLOUD COMPUTING BASED ON THE METHODOLOGY USED

we have categorized our results of challenges on seven different commonly used methodologies. The methodologies are survey, case study, SLR, OLR, experiment, formal methods, and mixed, as shown in Figure 1. By mixed, we mean that more methodologies are used in a paper. From the analysis, we concluded that the experiment had been conducted in most

TABLE 8. Practices for addressing SLA violation.

CC#5 SLA Violation		
S.NO.	Practices for Addressing SLA Violation	Frequency
CCP#5.1	Adopt the Hybrid VM Selection policy Algorithm to ensure the service quality to the user by lowering the violation of Service-Level-Agreement.	5
CCP#5.2	Usage of Energy-based-Efficient-Resource-Scheduling-Framework .i.e. EBERSF, is proposed for the cloud customer to provide the optimal outcomes and efficient services and guarantee to avoid the violations inside the service level needs.	17
CCP#5.3	Use of proposed heuristic likewise the Earliest-Deadline-First alongside with the DVFS and Approximate-Computations .i.e. EDF-DVFS-AC to consistently provide not only the lower power consumption but also, the lower SLA violations proportion and the total monetary price.	11
CCP#5.4	Utilization of Prediction-based-Minimization-of-Migration algorithm .i.e. PMM, where the migration originated when the SLA is violated in the present and the future the estimation of future is performed on predictions. The prediction in the current work is performed via the Markov-Chain model.	13

TABLE 9. Practices for addressing Lack of efficient provision of resources and services.

CC#6 Lack of efficient provision of resources and services		
S.NO.	Practices for Addressing Lack of Efficient Provision of Resources and Services	Frequency
CCP#6.1	Implement a Hybrid VM Selection policy **a**lgorithm for virtually cloud centers to continuously unite the migration of VM's live leveraging and turning off the idle nodes to lower the energy consumption.	25
CCP#6.2	Use of Virtualization technique to advance resource usage and provide the elasticity, consistency, and isolation of the performance.	18
CCP#6.3	Adopt a multi-application virtualized cluster in which the resources are owed to the applications by the priorities of these applications to confirm QoS parameters.	15
CCP#6.4	Adopt the Adaptive-Task-Allocation-Algorithm .i.e. ATAA, to license the preempted user tasks by the provided priority.	20
CCP#6.5	Adopt Energy-based-Efficient-Resource-Scheduling-Framework .i.e. EBERSF that might assist the cloud customers during the resource scheduling for optimum outcomes and efficient services, also guarantees the violation avoidance in the service level agreements.	9
CCP#6.6	Adopt SLA-aware resource allocation based on Technology Proficiency Self-Assessment (TPSA) policy to utilize the available resource.	5
CCP#6.7	Usage of Off-the-Cloud-Service-Optimization, .i.e. OCSO, a unique approach as a proactive and native level for service optimization, and can attain resource usage efficiently.	2
CCP#6.8	Adopt Green Cloud Scheduling Model (GCSM) to manage resources based on user requirements.	2

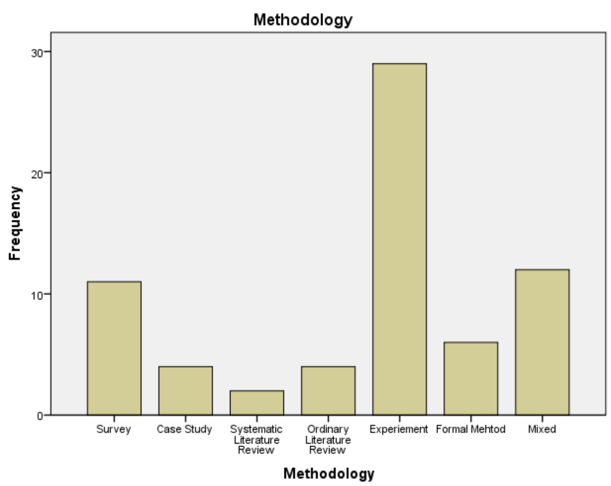

FIGURE 1. The methodology used in the SLR sample publications.

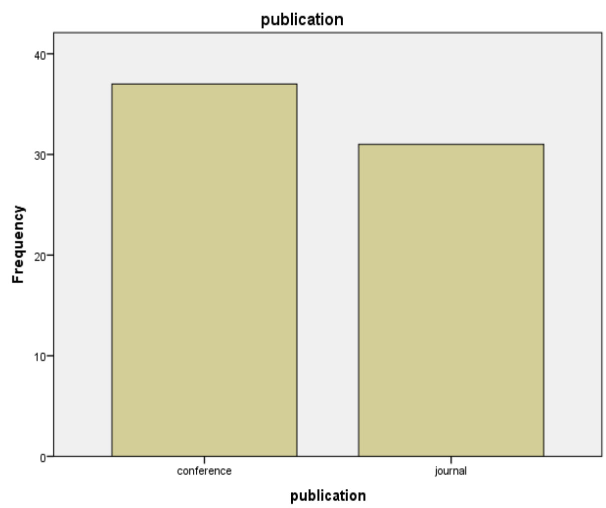

FIGURE 2. Distribution of SLR sample publications based on venues.

of the papers. It is because GCC goals can be achieved by improving existing systems. In summarizing, we can say that experiment is the very need for comparing the approach with other approaches. The second significant result that we have concluded was mixed methodology. The author first finds out approaches already exist and then formulate his approach to find the appropriate result.

C. ANALYSIS OF THE IDENTIFIED CHALLENGES IN GREEN CLOUD COMPUTING BASED ON YEARS

Figure 2 describes an analysis of challenges between two periods. We put no date boundaries during the execution of our SLR search. But as we have known that GCC's main contribution is started from 2009 onwards. We have divided

TABLE 10. Practices for addressing the Lack of green and sustainable infrastructures for the provision of reliable and cheaper services.

CC#7 Lack of Green and Sustainable Infrastructures for the Provision of Reliable and Cheaper Services		
S.NO.	Practices for addressing the Lack of Green and sustainable infrastructures for the provision of reliable and cheaper services	Frequency
CCP#7.1	Adopt the workload scheduling algorithm to lower down the brown power consumption, and where users can schedule their workloads dynamically and satisfy their demands via solar power efficiently.	15
CCP#7.2	Implement the Hybrid VM Selection policy algorithm that is an energy-efficient hybrid technique to lower the power consumption in a cloud environment and ensure the service quality to the user by lowering the violations of Service Level Agreements.	10
CCP#7.3	Adopt Rank-algorithm and Energy-Aware-Resource-Efficient-Workflow- Scheduling .i.e. EARES-D algorithm focuses on lowering the power consumption and CO_2 emission.	9
CCP#7.4	Adopt a multi-tenancy scheme that enables the flattening of complete peak demand and lowers the need for additional infrastructure and outcomes in the more significant power of savings.	13
CCP#7.5	Use a winner-determination algorithm to consider the strategic behaviour of every user and enhance the system's performance.	10
CCP#7.6	Adopt Energy-Efficient-Scheduling-Scheme .i.e., EESS allocates the workload on the lower amount of virtual devices for energy-saving purposes.	6
CCP#7.7	Use Green algorithms from the user's side to deliver encouragements to the users to lower power consumption.	11
CCP#7.8	Implement the genetic-based algorithm alongside the phase change for chip multiprocessors in a green-cloud environment. It also realizes the tradeoff for the memory utilization efficiency and the total processing time with scheduling tasks to cores.	6
CCP#7.9	Using light is good through which one can achieve the lighting and transition with the same power, which can be supposed as green energy because it safeguards the data without additional price. In terms of effectiveness, light fidelity .i.e. Li-Fi, delivers several advantages which raise the quality, the speed, and provides enough protection, etc.	8
CCP#7.10	Implement the Carbon-aware-green-Cloud architecture to increase the carbon footprint of the cloud, and at the same time, consider its universal view. This architecture is planned to provide motivations to both the users and the providers to use and provide green services, respectively.	17
CCP#7.11	Adopt a User-oriented-cloud-architectural-framework known as Carbon-Aware-Green-Cloud-Architecture that can address the atmospheric issues with the unlimited usage of cloud resources.	19
CCP#7.12	Use Proactive and Reactive Scheduling, .i.e. PRS, to accomplish good tradeoffs amongst the tasks promising ratio, use of system's resources, system's power consumption, and steadiness.	13
CCP#7.13	Implement Energy-aware-Dynamic-Task-Scheduling .i.e. EDTS algorithm based on DVFS and could lower down the power consumption, concurrently satisfying the rigorous time restrictions and the likelihood restraint of the Mobil-cloud environment applications.	21
CCP#7.14	Use Carbon-Aware-Green-Cloud-Architecture to raise the carbon footprint of cloud computing by looking concurrently at its universal view. The same can also provide motivations to both the users and the providers to use and provide the ever "Green" services, respectively.	16
CCP#7.15	Adopt CLEER-Model–Cloud-Energy and Emission-Research-Model, see [62], to deliver a comprehensive and user-friendly model to measure the net power and Green-House-Gas .i.e. GHG emissions of cloud-systems.	4
CCP#7.16	Adopt Task-Scheduling-using-Clonal-Selection-Algorithm .i.e. TSCSA that takes the responsibility to efficiently allocate the users' tasks into several available processing elements (PE) to optimize the power consumption as well time.	4
CCP#7.17	Energy-Aware SLA, which lies under the capacity of an energy-efficient SLA, specifies several needs to the provider upon asking to hold back the lower priority tasks for several periods .i.e. during the topmost time that will reduce once again the energy consumption.	3

TABLE 11. Practices to address the Lack of cybersecurity.

CC#8 Lack-of-Cybersecurity		
S.NO.	Practices to Addressing the Lack-of-Cybersecurity	Frequency
CCP#8.1	Novel-strong-user-Authentication-Protocol with Tree-based-Signature for green-cloud with numerous security assets likewise the identity management, the mutual authentication and establishing the session-key between the user and server.	4
CCP#8.2	Adopt light fidelity (Li-Fi) for users' self-security and overall management. Furthermore, the cybersecurity problems to data depend upon those used within a specific application domain.	1
CCP#8.3	Ensure that sensitive or private data be secured and monitored as an upper-level priority.	1
CCP#8.4	Use CyberGuarder as a security-assurance-architecture prepared for the operating system of NetApp. Furthermore, it works like a truly virtualized-based security resolution for the green-cloud environments. It also provides a trustable federation method for resource sharing among numerous resource pools.	1
CCP#8.5	Usage of cryptography-based-on-Li-Fi systems, which deliver cybersecurity resolutions with lower complexity, may enhance the storage capacity.	1

the papers into five years period. Period one is (2009-2014) and period two is (2015-2019). From the analysis, as shown in Figure 2, we may conclude that GCC is still one of the most critical areas of research because the majority of the papers are published in period two, such as (2015-2019).

D. ANALYSIS OF THE IDENTIFIED CHALLENGES IN GREEN CLOUD COMPUTING BASED ON PUBLICATIONS VENUE

Figure 3 present an analysis of the publication channel. We have developed two categories of publication channels.

TABLE 12. Practices for addressing Complexity in understanding cloud systems.

CC#9 Complexity in understanding Cloud systems		
S.NO.	Practices for Addressing Complexity in Understanding Cloud Systems	Frequency
CCP#9.1	Use green greedy algorithm; its low Complexity has a clear advantage over other algorithms.	2
CCP#9.2	Use CPN-based-Green-Cloud-Scheduler .i.e. CGCS, due to its cleanness, easiness, and uncomplicatedness.	1

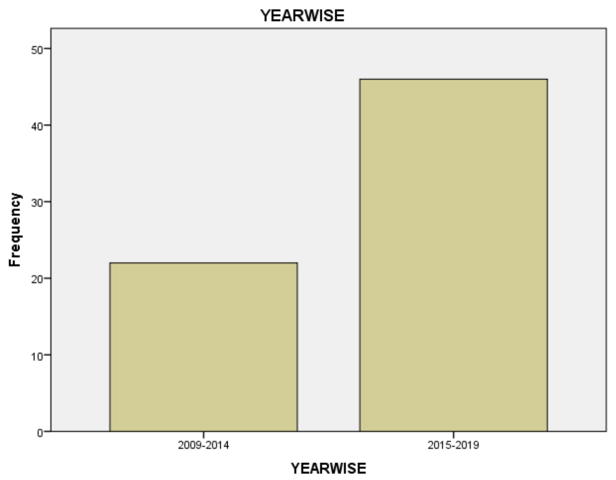

FIGURE 3. Distribution of SLR sample publications based on years.

We merge Workshops, symposiums into conference categories. The first author performed the merging both in consultation

In figure 1, X axis of the graph represent the group of methodologies used in the selected papers. Y axis of the graph shows the number of paper published in each group.

In figure 2, X axis shows the group of publication venues i-e conference, journal. Y axis shows the number of paper published in each group.

In figure 3, X axis of the graph represent the two periods i-e period 1 (2009-2014), period 2 (2015-2019). Y axis of the graph shows the number of publication in each period.

and recommendations of the secondary authors. Based on the analysis, we conclude that majority of the papers were from the conference channel. It may be because many conferences were held in the specific domain of GCC over the last decade.

E. PRACTICES/SOLUTIONS FOR CLIENTS TO ADDRESS CHALLENGES IN GREEN CLOUD COMPUTING

In total, 63 practices were identified to tackle the nine identified challenges. The details of these practices are presented in the rest of the tables, i.e., Table 4 to Table 12.

V. LIMITATIONS AND THREATS TO VALIDITY

We performed a systematic literature review as a research methodology to the best of our effort, including the applicability of suitable strings and a good enough sample. However, still, we can assume that there might be a chance that we have missed some valuable data. Furthermore, the study's keywords were used after a thorough discussion and suggestions by the two writers to ensure the study's validity and include as much relevant literature as possible.

To mitigate the risk of construct validity like the usage of digital libraries, we have conducted our search on the most relevant and well-known libraries of computing disciplines, see section (2) of III, but yet it was conducted on a limited number of libraries which might increase the chance of data being misused. For the internal validity of the study, we have listed the papers in Appendix A from which the data has been extracted for interested viewers to minimize the risk. To mitigate the risk, each phase of the SLR was validated through a systematic process and intervallic reviews by the contributing scholars. The rationale for such change was that the same technique had been used in the literature for similar studies. Another limitation or risk was that we had selected the papers only in the English language, which once again increased the chance of papers in the same domain.

Another limitation was that search results end in 2019. We will extend the results in our future publication to mitigate the risk. Furthermore, papers were selected from the English language only.

VI. CONCLUSION AND FUTURE WORK

Green cloud computing is a dire need today to overcome environmental issues. It may be concluded that clients are still facing many challenges in adopting green cloud computing. These challenges need to be adequately addressed. We have worked on the challenges, and we also find out practices to the identified challenges. Still, a lot of work needs to be done on client's perspective. In the future, we plan to validate the findings of SLR empirically via a questionnaire survey in the industry and dig out the similarities and differences in the findings of the SLR.

We will extend our search results from 2019 onward in our future publications. At the later stage, we plan to build a comprehensive framework by using robust soft computing techniques like Fuzzy logic or AHP, etc., to assist the clients in adopting GCC.

APPENDIX-A

See Table 13.

TABLE 13. Titles of the final selected papers.

Paper ID	Title of the final selected papers of SLR
1	A Taxonomy and Survey of Green Data Centers
2	SUITS: How to make a Global IT Service Provider Sustainable?
3	Energy Efficient Hybrid Policy in Green Cloud Computing
4	Providing Green SLAs in High Performance Computing Clouds
5	A Study on Energy Efficient Cloud Computing
6	Green Cloud Framework For Reducing Carbon Dioxide Emissions in Cloud Infrastructure
7	A Survey of Energy-Efficient Techniques in Cloud Data Centers
8	Challenges in Green Computing for Energy Saving Techniques
9	Green Cloud Computing: A Review on Green IT Areas for Cloud Computing Environment
10	Energy Aware Scheduling across 'Green' Cloud Data Centers
11	A Survey on Energy and Power Consumption Models for Greener Cloud
12	Energy Saving in Mobile Cloud Computing
13	Towards Greener Services in Cloud Computing: Research and Future Directives
14	An Analytical Evaluation of Challenges in Green Cloud Computing
15	A Survey Of Computing Strategies For Green Cloud
16	A Comparative Study of Resource Allocation Strategies for a Green Cloud
17	Envisioning Cloud of Energy
18	A Novel Authentication Protocol with Tree-based Signature for Green Cloud Computing
19	Cloud and Energy Management – Issues and Concerns
20	Elasticity Debt Analytics Exploitation for Green Mobile Cloud Computing: An Equilibrium Model
21	Energy-Efficient task scheduling in cloud data center- A temperature aware approach
22	Analysis of Cybersecurity based on Li-Fi in green data storage environments
23	An Auction-based Resource Allocation Model for Green Cloud Computing
24	Improving Cloud Computing Energy Efficiency
25	Efficient Energy Consumption in Green Cloud
26	Energy Saving Approaches for Green Cloud Computing: A Review
27	Energy Efficient and CO2 Aware Cloud Computing: Requirements and Case Study
28	Green Manufacturing Service Composition in Cloud Manufacturing System: an Introduction
29	AI Powered Green Cloud and Data Center
30	Spatial Task Scheduling for Cost Minimization in Distributed Green Cloud Data Centers
31	A Resource Evaluation Model Based on Entropy Optimization toward Green Cloud
32	Lowering Down The Cost for Green Cloud Data Centers by Using ESDs and Energy Trading
33	Temperature Aware Resource Scheduling in Green Clouds
34	A Green Mechanism Design Approach to Automate Resource Procurement in Cloud
35	Survey on prediction models of applications for resources provisioning in cloud
36	Thermal-benchmarking for cloud hosting green data centers
37	Towards Energy-Efficient Scheduling for Real-Time Tasks under Uncertain Cloud Computing Environment
38	Can cloud computing be labeled as "green"? Insights under an environmental accounting perspective
39	Model-driven auto-scaling of green cloud computing infrastructure
40	Dynamic energy-aware cloudlet-based mobile cloud computing model for green computing
41	Towards energy management in Cloud federation: A survey in the perspective of future sustainable and cost-saving strategies
42	Energy Efficient Task Scheduling in Cloud Environment
43	Energy Aware SLA with Classification of Jobs for Cloud Environment
44	GreenSched: An intelligent energy aware scheduling for deadline-and-budget constrained cloud tasks
45	Can everybody be happy in the cloud? Delay, profit and energy-efficient scheduling for cloud services
46	CyberGuarder: A virtualization security assurance architecture for green cloud computing
47	Sustainable Cloud Data Centers: A survey of enabling techniques and technologies
48	The uncertain cloud: State of the art and research challenges
49	An energy-efficient, QoS-aware and cost-effective scheduling approach for real-time workflow applications in cloud computing systems utilizing DVFS and approximate computations
50	Reinforcement learning based methodology for energy-efficient resource allocation in cloud data centers
51	Internet of Things applications: A systematic review
52	Tradeoff between Performance and Energy Management in Autonomic and Green Data Centers
53	GreenCloud: A New Architecture for Green Data Center
54	Green Cloud: Energy-aware Task Scheduling Strategies with QoS Constraint for Green Computing in Cloud Data Centers
55	Usage of Hybrid Mechanisms to Reduce Energy Consumption while Preserving Green SLA in Cloud Environment
56	Energy aware resource allocation of cloud data center: review and open issues
57	Green Cloud on the Horizon
58	Improving the Energy Efficiency in Cloud Computing Data Centers Through Resource Allocation Techniques
59	Energy-efficient migration techniques for cloud environment: a step toward green computing
60	OCSO: Off-the-cloud service optimization for green efficient service resource utilization
61	Green Cloud Framework for Improving Carbon Efficiency of Clouds
62	Energy aware scheduling of deadline-constrained tasks in cloud computing
63	Performance analysis based resource allocation for green cloud computing
64	Optimization of Application Placement Towards a Greener Cloud Infrastructure
65	QoS- and Energy-Aware Services Management of Resources in a Cloud Computing Environment
66	Green Cloud Computing Using Proactive Virtual Machine Placement: Challenges and Issues
67	An adaptive task allocation technique for green cloud computing
68	An optimal control policy to realize green cloud systems with SLA-awareness

TABLE 14. Classification of the study based on methodology, year, and publication venue.

Paper ID	METHODOLOGY	YEAR	PUBLICATION
1	SURVEY	2015	CONFERENCE
2	FORMAL METHODS	2012	WORKSHOP
3	EXPERIMENT	2015	CONFERENCE
4	EXPERIMENT	2013	JOURNAL
5	SURVEY	2015	CONFERENCE
6	EXPERIMENT	2019	CONFERENCE
7	SURVEY	2013	CONFERENCE
8	SURVEY, EXPERIMENT	2017	CONFERENCE
9	SURVEY	2015	CONFERENCE
10	CASE STUDY	2013	SYMPOSIUM
11	SURVEY	2012	CONFERENCE
12	ORDINARY LITERATURE REVIEW	2013	CONFERENCE
13	ORDINARY LITERATURE REVIEW, EXPERIMENT	2015	CONFERENCE
14	ORDINARY LITERATURE REVIEW	2017	CONFERENCE
15	SURVEY	2016	CONFERENCE
16	SURVEY	2016	CONFERENCE
17	FORMAL METHODS	2015	CONFERENCE
18	EXPERIMENT	2018	CONFERENCE
19	ORDINARY LITERATURE REVIEW	2015	CONFERENCE
20	EXPERIMENT	2018	JOURNAL
21	EXPERIMENT	2019	CONFERENCE
22	EXPERIMENT	2017	CONFERENCE
23	FORMAL METHOD,EXPERIMENT	2013	CONFERENCE
24	ORDINARY LITERATURE REVIEW, EXPERIMENT	2012	JOURNAL
25	EXPERIMENT	2014	CONFERENCE
26	ORDINARY LITERATURE REVIEW	2014	CONFERENCE
27	CASE STUDY	2013	CONFERENCE
28	FORMAL METHODS	2016	CONFERENCE
29	FORMAL METHODS	2018	JOURNAL
30	EXPERIMENT	2018	JOURNAL
31	EXPERIMENT	2014	CONFERENCE
32	ORDINARY LITERATURE REVIEW, EXPERIMENT	2016	JOURNAL
33	EXPERIMENT	2013	CONFERENCE
34	EXPERIMENT	2015	CONFERENCE
35	SURVEY	2017	JOURNAL
36	EXPERIMENT	2019	JOURNAL
37	ORDINARY LITERATURE REVIEW, EXPERIMENT	2015	JOURNAL
38	CASE STUDY	2017	JOURNAL
39	ORDINARY LITERATURE REVIEW, CASE STUDY	2012	JOURNAL
40	ORDINARY LITERATURE REVIEW, EXPERIMENT	2016	JOURNAL
41	SURVEY	2015	JOURNAL
42	EXPERIMENT	2018	CONFERENCE
43	EXPERIMENT	2015	CONFERENCE
44	EXPERIMENT	2018	JOURNAL
45	EXPERIMENT	2016	JOURNAL
46	FORMAL METHOD, EXPERIMENT	2012	JOURNAL
47	CASE STUDY	2016	JOURNAL
48	SURVEY, CASE STUDY	2016	JOURNAL
49	EXPERIMENT	2019	JOURNAL
50	EXPERIMENT	2018	JOURNAL
51	SYSEMATIC LITERATURE REVIEW	2018	JOURNAL
52	FORMAL METHOD	2019	CONFERENCE
53	EXPERIMENT	2009	CONFERENCE
54	EXPERIMENT	2018	CONFERENCE
55	SURVEY	2016	CONFERENCE
56	SURVEY	2016	JOURNAL
57	FORMAL METHODS	2009	CONFERENCE
58	SURVEY, CASE STUDY	2017	JOURNAL
59	EXPERIMENT	2019	JOURNAL
60	EXPERIMENT	2014	JOURNAL
61	FORMAL METHOD, CASE STUDY	2011	CONFERENCE
62	EXPERIMENT	2016	JOURNAL
63	EXPERIMENT	2013	JOURNAL
64	EXPERIMENT	2014	CONFERENCE
65	EXPERIMENT	2018	JOURNAL
66	SYSTEMATIC LITERATURE REVIEW	2019	JOURNAL
67	EXPERIMENT	2017	JOURNAL
68	EXPERIMENT	2014	JOURNAL

APPENDIX B

See Table 14.

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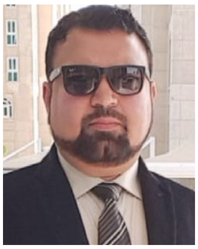

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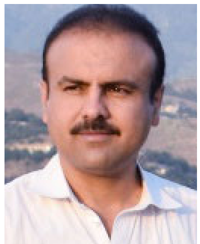

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