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Ant Colony System (ACS) Algorithms: A Performance Review on Energy Saving Strategies

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Abstract:-The rapid growths in demand for computing resources and shift to Cloud Computing (CC) paradigm have necessitated the establishment of Virtualized Data Centers (DCs) known as Server Farms. In these centers, computing resources are virtualized, which consequently consume enormous electrical energy. This theoretical review presents background information and assess topic in a state of flux relating to energy-saving criteria in DCs using Ant Colony System (ACS) algorithms. The purpose is to avail its readership both early and mid-career researchers in computer discipline; critical literature review, existing research gaps and comprehensive bibliography as reference materials. Also, a literature review on other energy reduction using greedy approaches is included. Furthermore, sources of this review, research tools used by previous authors, adopted energy-saving strategies, taxonomy of ACS variants and reputable World's publishers were analyzed. These are expected to pave way for the laying foundation in future research works.

Keywords:- *Cloud Computing, Virtualization, Virtualized Data Centers, Virtual Machine Consolidation/Placement, Ant Colony System.*

I. INTRODUCTION

Virtualized Data Centers (DCs) are the stations comprising a pool of PMs with different resource capacities. They run various applications and services purposely to serve users. These centers face many setbacks; among winch is energy consumption and environmental degradation. In an attempt to solve these problems, the cloud computing (CC) paradigm emerged. The essence of CC is to provide virtually infinite computing resources; storage, memory, communication etc as pay-as-use business model. This new technology can only be achieved through virtualization process. Virtualization creates Virtual Machines (VMs) on top of physical machines (PMs) aimed to increase resource utilization and improve quality of service (QoS) requirements. The DCs considered energy consumption and its consequences to environmental degradation as critical issues of concerned. They, therefore, require various measures to minimize these and many other issues affecting them. Among such strategies is Virtual Machine Consolidation (VMC) which maps a set of VMs to PMs. The techniques mostly used are the migration of VMs from source to destination PMs thereby reducing the number of active servers or increasing the number of sleeping PMs. Virtualization leads to high operational costs (Beloglazov & Buyya, 2012; Beloglazovy & Buyya, 2011). The optimal mapping of tasks to Virtual Machines (VMs) and VMs to Physical Machines (PMs) is Virtual Machine Consolidation (VMC) problems, which helps in energy optimization. Many approaches proved effective via live migration and switching idle PMs to a sleep state. VMC allows Cloud Service Providers (CSPs) to optimize resource and reduce energy leveraging the Quality of Service (QoS). It avoids host's low-resource usage, because VMs on slightly loaded PMs are packed onto fewer PMs to meet resource requirement (Verma & Tripathi, 2018).

Many approaches were adapted in trying to reduce energy/electrical power consumption; (Aryania, Aghdasi, & Khanli, 2018; Duan, Chen, Min, & Wu, 2017; Pham & Le, 2017; Prasad Devarasetty & Reddy), etc. These researchers considered VMC as NP-Hard. This is because, solving VMC issues through constraint, linear programming and other greedy approaches remained deficient. As such, the inspiration of animals, birds, fishes, and insects help the computer solves tasks easily.

(Venables, 2011) Ant Colony System (ACS) is mostly used as it adapts the behavior of natural ants in problems solving issues such as VMC. The ants' behavior includes communication strategy, systematic deposition of deceased bodies, brood sorting and colony welfare, hierarchical systems. Other behaviors of natural ants are cooperative transport, foraging strategies, division of labor based on morphology, age or chance. These made ACS have been widely used in various domains and demonstrated the utmost efficiency in solving real-life problems. (Deepa & Senthilkumar, 2016) opined that ACS is relevance as a computer science discipline. It is similar to Artificial Bee Colony (ABC), Particle Swarm Optimization (PSO), Genetic Algorithm (GA), Differential Evolution (DE) and a subset of Swarm Intelligence (SI). SI is a technique for solving computational problems, which can be used to get optimal solutions.

(Aryania *et al.*, 2018) Cloud Computing (CC) provides access to computing resources to its various users; CPU, RAM, HDD etc. It is being managed by Cloud Service Providers (CSPs). The CSPs offer essentially three (3) services; Infrastructure as a Service (IaaS), Software as a Service (SaaS) and Platform as a Service (PaaS). These resources are shared through virtualization. It is through VMC in CC that VMS is created on top of PMs for the execution of users' applications questing for resources.

In a nutshell, a brief survey conducted using reputable sources; IEEE, Springer, Elsevier, ACM, and Taylors & Francis motivated the current proposal. It can be inferred that most of these researches consulted suggested various optimization approaches. They exploited several objectives; a number of migration, number of active or sleeping servers, the variance between servers used capacity and energy consumptions. Furthermore, most of these researchers aimed at reducing total energy consumption in Virtualized Data Centers (DCs).

The review is motivated by the current survey on the use of ACS algorithms for energy consumption reduction through VMC, which proved successful. According to (Stoft, 2002) power is the rate of flow of energy and the ability to produce power is itself a flow. A megawatt (MW) of capacity is worth little if it lasts only a minute, what if MW of power or capacity that flows for a year? It is quite valuable! The price of both power and energy is worthy of measurement.

However, despite many reviews were on record (Khan, Paplinski, Khan, Murshed, & Buyya, 2018; Nayak, Naik, Jena, Barik, & Das, 2018). Also, despite wider applications and several enhancements of ACS algorithms for energy reduction strategies, still other issues remain unresolved. The novelty of the current review as it contains research gaps left and tools used by previous authors, adopted energy-saving strategies, a taxonomy of ACS variants as well as reputable World's publishers were analyzed. These will lay a foundation for future research in energy conservation in DCs through various means. It is expected to advance knowledge, have values, of interest to cloud users/ant colony and benefit Cloud Service Providers (CSP). Furthermore, it may be good for novice and other researchers as reference material.

The rest of the outline/topology of this review used (Nayak et al., 2018) as a benchmark: 1.1 Introduction, 1.2 An overview on Cloud Computing, 1.3 Emerging Research Areas 1.4 Analysis & Discussion, 1.5 Further Research Challenges, and 1.6 Conclusion. Finally, references, curriculum vitae and photos of the authorships.

II. AN OVERVIEW ON CLOUD COMPUTING

This review revealed that the paradigm shift towards the development of the VMC technique leads to the contributions from various research communities' on Ant Colony System (ACS). This is because DCs' products and services are being simplified and modernized for efficient delivery. Cloud services are popular and highly demanded due to flexibility, availability, and accessibility of resources as per users' choice on hype. (Malhotra *et al.,* 2014) Cloud Computing (CC) is a new business based on virtualization, multi-tenancy and shared infrastructure. In it, all data are stored in the servers, accessible by authentication via the internet across the globe. The major cloud service providers include Apple, Google, and Microsoft among others; provide large storage to users and making work easier. (Nayak *et al.,* 2018) further stated CC a distributed and parallel computing environment consisting of a huge collection of virtualized and inter-connected computing resources dynamically presented and provisioned based on Service Level Agreement (SLA). Also, (Deepa & Senthilkumar, 2016) CC is built based on two features; Virtualization and Service-Oriented Architecture (SOA). This provides services to the customers accessible and usable. These features also provide the base for the development of a Cloud Computing environment. (P. Li *et al.*, 2018) CC is the delivery of computing services; servers, storage, databases, networking, software, analytics and more, over the Internet. It is supported and maintains by companies called cloud providers. Also, it allows computing devices and services delivery for the sharing of storage and network resources to its clients. Hence, the CC usage is flexible, helps in cutting costs to the end-user and allows application development environment, data storage, back up, recover, host websites and blogs. Others are stream audio and video services, deliver software based on demand or data Analyses

➢ *Layered architecture*

(Nayak *et al.*, 2018) cloud computing services (CCS) are broadly classified based on the abstraction level of ability and service provided by the service provider. This abstraction level can also be represented as layered architecture in a cloud environment. The layered architecture of cloud computing can be represented by four layers such as the data center layer, platform layer, infrastructure layer and application layer. Datacenter Layer accounts for managing physical resources such as servers, switches, routers, power supply, and cooling systems. Infrastructure Layer is a virtualization layer where physical resources are partitioned into a set of virtual resources through different virtualization technologies. Platform Layer deploys application software and operating system directly on the virtual machines. Application Layer consists of different actual cloud services that provide services to the end-user as per their requirements.

➢ *Business model*

(Nayak *et al.*, 2018) CC is supported by VMC as a model of services. These models are Software as a service (SaaS) based on online subscription, licensing, delivery model and central hosting. It eases the problem of buy and installs software on individual computers. SaaS removes bought, installed and run applications on individual computers or data centers. It also eliminates acquisition expense, provisioning, maintenance, licensing, installation and supports. This model of delivering services is called Software as a Service (SaaS). (Ferraz, Ribeiro, Lima, & Sampaio, 2018) there is exists companies that provide these services. CC eliminates the overhead of software maintenance and simplifies the development process of end-users. Examples of PaaS providers are Rackspace and salesfource.com. Also, As such, a SaaS company hosts an application and makes it available over the internet. This infers that the software sits on SaaS Company's server while the user accesses it remotely. Infrastructure as a service (IaaS) as reported in (Ferraz *et al.*, 2018; Mahmud, Kotagiri, & Buyya, 2018) CC provider supplies many services that include; infrastructure components, data centers, servers, storage, and networking hardware. Therefore, IaaS provide customers' access to resources and services through a wide area network (WAN). Again, (Mahmud *et al.*, 2018) CC provides an enabling environment for quick application development, test, deployment, scalable virtual environment based on the need and demand of a client. It further supports websites hosting in a robust and secure platform, handles big data storage, backups, and recovery, high-performance computing among others. Platform as a service (PaaS) enables a platform and environment for a developer to build an application and enjoy services over the internet. (Furht & Escalante, 2010) CC provides database management systems and development tools for complete web application's lifecycle; building applications, testing, deploying, managing and updating.

➢ *Cloud Types*

Four types of clouds exist; public, private, hybrid and community. A public cloud is owned and operated by CSPs to customers as a pay-as-you-go model. This provides public and global access to a computing resource. Vendors include Google, Amazon, and Microsoft, etc. A private cloud as the name implies, it provides private access to a single enterprise but secured by the public cloud. The hosting is either done internal or external with other CSPs. As such, services are owned, provided and managed by the enterprise itself. Its vendors include Vmware, IBM, HP, and Oracle, etc. The hybrid integrates both features of public and private clouds. In it, secured services are provided by the private and other services by the public clouds respectively. Services search as ERP is in Private while emails on public clouds too. The community-based cloud is owned and managed the infrastructure of numerous communities. Also, hosting as in Hybrid cloud.

➢ *Research Challenges on Energy Saving Strategies*

Several research efforts to save energy in DCs using task scheduling, resource allocation, cloud federation, virtual machine consolidation (VMC), energy efficiency, and load balancing among others were on records. For instance (Duan *et al.*, 2017) proposed an ACO *PreAntPolicy* algorithm; factual mathematics prediction and improved scheduling. This model determined whether or not to trigger the scheduler due to load trend prediction. Its concern is resource scheduling, reducing energy consumption and guaranteeing QoS. They used computer clusters of Google real workload under CloudSim, which reduced energy, exhibits excellent energy efficiency and resource utilization. (Shabeera, Kumar, Salam, & Krishnan, 2017) proposed an ACO NP-Hard technique *MinDistVmDataPlacement* algorithm aimed at reducing cross-network traffic and bandwidth usage. The algorithm placed the required number of VMs and data into PMs that are physically closer. Its performance proved better in allocation schemes. (X. Liu *et al.*, 2017) proposed architecture for energy-aware Network-on-Chip (NoC). They used ACO and the technique superseded others in addressing slow convergence. (Liu *et al.*, 2016) developed an Order Exchange and Migration Ant Colony System (OEMACS) strategy. The strategy employed artificial ants towards grouping candidates VMs together. It was tested on both homo and heterogeneous servers. The experimental results proved better than other conventional heuristic and evolutionary based approaches.

In the subsequent year, (Ashraf & Porres, 2018) presented the Multi-objective Ant Colony System (MACS) algorithm for VMC that addressed VM migration plans. The objective was to minimize PMs over-provisioning. This algorithm maximized the number of release PMs (ACS_{PR}) and minimized VM's migration (ACS_{nm}). It was empirically evaluated in many experiments but outperformed. (Liu, Zhan, & Zhang, 2017) proposed a live migration as an energy reduction approach. Later found that the frequency of live migration leads to a down service. They in-turn proposed DVMP_ Unified Ant Colony System (UACS) addressed hosting of VMs through the fewest servers. Its assignment evaluation on both under large-scale random workloads and real workload traces but yet proved most efficient. (Moon, Yu, Gil, & Lim, 2017) proposed a Slave Ant Colony Optimization (SACO) by *Diversification & Reinforcement Strategies* (DRS). The SACO avoided long path with wrongly accumulated pheromone guided by the leading Ants. The method allocated tasks of users to VMs and maximally utilized cloud servers. (Pang, Zhang, Ma, & Gao, 2017) introduced a Dynamic Energy Management System (DEMS) model based on the ACO algorithm. The technique comprised of Management, Load Balancing, and task Scheduling Modules. The running time and energy consumption leveraging task scheduling tasks were optimized. It was proved that DEMS outperformed Round Robin (RR) by saving up to 40% energy consumption. (Pham & Le, 2017) reduced the number of PMs as a means of reducing energy consumption, which in turn improved the performance of the DCs. A *Multi-Objective Resource Allocation (MORA-ACS* is used and the experimental results showed that not only ensured load balancing but proved better than Round Robin (RR). (Tiwari, Richhariya, & Patra, 2017) proposed an Ant Colony mechanism for VM allocation/placement to manage computing resources. They used a graph and considered each PM as a node; each edge defines a VM migration from one PM to another. The generated graph is directed and completely connected having +ve edge weights. A threshold graphical analysis showed that the ACO threshold is the most effective over static and dynamic approaches. (Moorthy, Fareentaj, & Divya, 2017) developed Optimal Virtual Machine Placement (ACO-OVMP) for effective utilization of resources and higher profit. The process had in turn provided appropriate resources to the clients. Comparisons on response time, number of migrations, resource wastage and costs with other greedy mechanisms were made. It showed that ACO-OVMP outperformed in all comparisons. (Kaewkasi & Chuenmuneewong, 2017) proposed a method to improve observed sub-optimality of a non-uniform resources in Docker. This problem is an NP-Hard and suggested for meta-heuristic; ACO algorithm. The implemented new scheduler effectively distributed application containers over Docker's host as well as balanced the resources better performance over the previous approaches by 15%.

(Aryania *et al.*, 2018) considered energy consumption during VMs migration and proposed a new VMC Ant Colony System (ACS) based on energy-saving DCs. The approach saved energy, reduced the number of migrations, active and increases the number of sleeping PMs. The simulations random workloads proved that the new technique not only outperformed but leveraged SLA violations. (Qin, Wang, Zhu, & Zhai, 2018) formulated a Bin Packing Problems (BPP) for VMs placement using a multi-objective ACS; Bin Packing Virtual Machine Placement (ACS-BVMP). The algorithm maximized revenue of communications and minimized the power consumption of PMs. It tested in many instances yet showed an outperformance over other algorithms. (Hasan *et al.*, 2018) addressed prone to error and high energy input demands of the problems of mobile CC. They used to cost and run-time effective model that created a minimum energy configuration of cloud compute nodes and guaranteed minimum SLA violation. It proved effective as it reduced energy by 42%, SLA violation and number of calculations over static approaches. (Verma & Tripathi, 2018) proposed an algorithm for VM allocation and migration employing a meta-heuristic Ant Colony based. They applied the Rank Based Ant System (RBAS) on VM allocation and migration. The approach was found in better performance. (Kanthimathi & Vijayakumar, 2018) hybridized GA with ACS for improved QoS. Metrics optimized are response time, cost, throughput, performance, and resource utilization. They enabled the server to handle incoming requests with available VMs and allowed extra VMs to execute without fault or delay. They add more VMs using GA and the load balancing was made via ACS technique. The method saved energy by switching off VMs at idle state of on completion of the assigned task(s). (Rani & Garg, 2018) minimized the total power consumption taking into account IT equipment and cooling power consumptions as parameters. They developed Power-Aware (PA-ACO) algorithm which mapped VMs to PMs. The result showed outperformance over the Min-Min algorithm.

(Prasad Devarasetty & Reddy) proposed an article in the press that succeeded in reducing resource wastage, energy consumption and communication costs based on Multi-Objective (MOACO). The performance of the approach was evaluated and showed that it proved efficient. (Wei, Gu, Lu, Zhou, & Liu, 2019) proposed an energy-efficient VMP based on Adaptive Parameter (AP-ACO) improved. They reduced energy over network and communication cost. The technique proved better improvements on the set objectives. (Rubaiee & Yildirim, 2019) minimized total computation time and energy costs. They used a Multi-Objective heuristic (MOACO) algorithms; Weighted Sum Method (WSM), Dominance Ranking (DR) and Multi-Objective Optimization on the based on Ratio Analysis (MOORA). The performance allowed better decision making in the IIoT ecosystem and assisted in production planning for improved energy cost. (Farshin & Sharifian, 2019) proposed a Grey-Wolf-Optimization Knowledge-based modified ACS for the placement of Virtual Network Functions (VNFs). They again simultaneously allocated main and redundant paths to flows for service. In addition, the algorithm distributed fairly the service-chaining on various cloudlets connected to routers where the services use CPU utilization and memory efficiently. The approach utilized physical resources, achieved lower delay and high bandwidth for VNFs better than PSO. (W. Deng, Xu, & Zhao, 2019) developed an Improved ACO Multi-Population Co-evolution (ICMPACO) based on pheromone update strategy and diffusion mechanism. The essence of the approach is to balance convergence speed, solution diversity and improve performance by dividing the natural ants into *elites* and *common*. The former is improved convergence and the later avoided local optima value. The updating improved optimization ability while the diffusion made the released pheromone at a certain point. Also, the co-evolution is for information exchange among different sub-population and the technique outperformed TSP instability. (Alharbi *et al.*, 2019) embedded an ACS with new heuristics for VMs placement to PMs, which reduced total energy consumptions of active PMs. The algorithm outperformed ACS-FFD in energy saving at small, medium and large scales DCs. (Xiao, Hu, & Li, 2019) proposed Dynamic Allocation (DAVMC-ACS) based on double thresholds (DT). The aim is to improve QoS, minimize energy consumption and migration overhead. In this, VMC is triggered only when the host load status is either under or overloaded. The selection of the migrating VMs and the destination host is based on ACS diverse selection policies of hosts' load status. The approach is validated with other state-of-the-art VMCs; thus achieved better performance.

Other static energy-saving strategies included (Hao, Kodialam, Lakshman, & Mukherjee, 2017) proposed an online and generalized placement for various cloud architectures. The allocation is done with no prior knowledge of any future resource and permitted many future arriving requests. The experimental outcomes showed the superior performance of the current practice. (Nadjar, Abrishami, & Deldari, 2017) developed a memory, application, thermal and NetWare VMP for power-aware, migrations cost and SLA metrics. They accumulated VMs on fewer numbers of hosts (PMs) while maintaining QoS. They further classified VMP strategies and proposed different combinatorial placement policies that considered load dispersion of hosts; over/under load is equal to[upper load > threshold < lower load. Also, the health parameter as the fraction of CPU-MIPS capacity of host-related to total demanded Million Information per Second (MIPS) running was considered. (Goudos, 2016) proposed a new Biogeography-based Optimization (BBO) for the reduction of Partial Transmit Sequences (PTS). They also proposed a new Generalized Oppositional BBO (GOBBO) algorithm, which was enhanced with Oppositional Based learning (OBL) techniques. The two methods were applied to solving PTS problems. The GOBBO was compared with other PTS schemes; Peak to Average Power Ratio (PAPR) reduction and proved highly efficient. (Hirsch, Rodríguez, Mateos, & Zunino, 2017) designed a two-phase scheduling approach for executing CPU-intensive jobs and mobile devices. They combined novel energy-aware criteria with job-stealing modeling CPU usage. In the first phase, they evaluated a battery-based consumption simulator extracted from real mobile devices. This was compared with a number of finalized jobs of all energy-aware criteria. In the second phase and analyzed the performance by job stealing. Experiments showed that the first phase finalized up to 90% submitted job while in the second phase increased by 9%.

(Reddy, Gangadharan, & Rao, 2019) proposed a Modified Discrete Particle Swarm Optimization (MDPSO) algorithm for VMP and VM selection. They optimized current VM allocation based on the size of VM, memory and bandwidth utilization. The technique saved energy and minimized SLA violations. (López-Pires, Barán, Benítez, Zalimben, & Amarilla, 2018) considered a novel two-phase optimization for resolving VMP issues considering power consumption, economic revenue, resources' utilization and re-configuration time metrics. The technique used VMs' migration between PMs, assigned tasks and showed outperformance as compared with other state-of-the-art alternatives. (H. Deng, Huang, Yang, Xu, & Leng, 2017) modeled the response latency of requests from tenants as independent Poison Stream. The performance of the algorithm was analyzed and proved efficient. While (Gupta & Amgoth, 2018; Gupta, Jain, & Amgoth, 2018) minimized power consumption by reducing the number of active PMs on Amazon EC2 and the unbalanced resource utilization among PMs. The model limited the migration of VMs and demonstrated superior performance over the existing ones. (Ghobaei-Arani, Shamsi, & Rahmanian, 2017) employed a power-efficient mechanism and placed VMs on PMs as a means of power cost reduction. Also, considered are the maximum absolute deviation during VMs placement and SLA deviations via best fit decreeing (BFD) and decreased 5% and 6% power and SLA as compared with other greedy approaches. (Fard, Ahmadi, & Adabi, 2017) minimized the number of active PMs and consequently optimizes energy consumption through VMP and migration. Furthermore, a novel VMC for energy-QoS-Temperature balance was proposed. The evaluation of the technique proved effective to control energy consumption. (Lim, Yu, & Gil, 2017) formulated an efficient energy-aware cloud consolidation algorithm for multimedia Big Data applications. They opined that the use of live migration of VMs was unsuitable. TAs such proposed "Applications Types" instead. This algorithm was assigned tasks on VMs, considered trade-off between the number of VMs and I/O bottlenecks. Three (3) correlated parts; pre-processing, VM monitoring task and VM assignment were achieved. (Wen, Li, Jin, Lin, & Liu, 2017) proposed an energy-efficient virtual resource dynamic integration (VRDI). It monitored load patterns of the PMs and calculated their corresponding threshold based on statistical data. Also proposed, is a PM selection algorithm for finding PMs to be consolidated/integrated. In addition, proposed VM selection based on minimum migration policy integrated VMs on PMs. Furthermore, VMP based on an improved Genetic Algorithm (GA) was used. Finally, encoding, cross-over and mutation operations were employed. The process reduced energy consumption of DCs more than other greedy algorithms. (Kansal, Zhao, Liu, Kothari, & Bhattacharya, 2010) amalgamated ABC and FA algorithms as a novel energy-aware and load balancing of cloud infrastructure. The competency of the approach was validated with RR, FFD, and ACO. The method proved efficient by saving up to 40.47% average energy consumption, improved CPU and memory utilization levels by 49.68% and 24.41% respectively. Also, reduced VMs migration and saved nodes by 53.10% and 53.21% respectively.

(Kumar, Yadav, Khatri, & Raw, 2018) proposed a global host allocation with a goal of reducing energy consumption, resource utilization and avoidance of SLA degradation. The Upper and Lower Thresholds Policy adopted and collected unallocated resources to new VM requests. (Ranjbari & Torkestani, 2018) proposed a novel algorithm based on learning automata. The algorithm improved resource utilization, reduced energy consumption, prevents server overload, shutdown idle servers, reduced migration and predicted PM based on users' demand to resources. The technique superseded Dynamic Voltage Frequency Scaling (DVFS) with 175.48Kwh, 0.00326 in energy consumption and SLA violation respectively. (Wang & Tianfield, 2018) developed a framework known as Dynamic VMC for green cloud computing and utilized two policies; VMP [Space Aware Best Fit Decreasing (SABFD)] and new migration VM selection [high CPU utilization based migration selection (HS)] respectively. The combined policies proved the best performance than DVMC. (Han, Que, Jia, & Zhang, 2018) proposed resource-utilization-aware energy-efficient server consolidation (RUAEE), which balanced resource utilization among t PMs and reduced the number of VM live migration. The experiment proved that while reducing energy SLA violations were also minimized. (Li, Yan, Yu, & Yu, 2018) proposed an energy-aware Dynamic VMC (EC-VMC), which migrated VMs while satisfying constraints on the probabilities of multiple resources being overloaded. Also, integrated and co-operated the algorithm similar to ACS foraging behavior for an optimized search for VMs consolidation. An extensive simulation revealed that EC-VMC outperforms an ordinary VMC in ensuring QoS other assigned tasks. (Zhou *et al.*, 2018) addressed high energy consumption with minimal SLA violations. Two novel adaptive energy-aware were used; maximizing energy efficiency and minimizing SLA violation rate. Application types, CPU and memory resource during VMs deployment were considered. They used real-world workload of 1000+ VMs from PlanetLab and the algorithm outperforms the existing energy-saving techniques. (Abdel-Basset, Abdle-Fatah, & Sangaiah, 2018) minimized the number of running PMs with respect to bandwidth. They formulated the available bandwidth as a variable-sized in Bin Parking Problems (BPP). Furthermore, a new bandwidth allocation policy is developed and hybridized with Whale Optimization Algorithm (WOA) known as an Improved Levy Based (ILB-WOA). The algorithm was compared with original WOA, Best Fit (BF), First Fit (FF), PSO, GA and Intelligent

Turned harmony Search (ITHS) algorithms and proved prosperity in all cases measured. (Mishra et al., 2018) proposed a complete mapping (i.e task to VM and VM to PM) algorithm. The tasks are categorized based on resource needs, then search for appropriate VM and its host PM. The technique reduced energy consumption, makespan and task rejection rate. (Callau-Zori, Samoila, Orgerie, & Pierre, 2018) sought for an energy model, which estimates energy associated with VM's management operation; VMP, VM start-up and VM migration. The technique proved estimation error of 10% lower than the transactional web bench mark. The algorithm is considered a good candidate for driving actions of future energy-aware cloud management system. (Zhang *et al.*, 2019) introduced a novel and effective evolutionary approach for VMs allocation aimed at minimizing energy while incorporating more reserved PMs. They designed a simplified simulation engine for CloudSim that accelerates the evolutionary approach. The result proved better allocation for batch reserved PMs and VMs consolidated on fewer PMs, which enabled DCs to save more tenants requests. (Cocaña-Fernández, Rodríguez-Soares, Sánchez, & Ranilla, 2019) proposed a proactive multi-objective mechanism for virtual VDC optimization through server consolidation. A multi-objective evolutionary algorithm to learn the Fuzzy rule-based system was used. These determined the optimal allocation decision based on preferences of VDC operator and load prediction. The experimental evaluation based on actual CSPs improved energy saving and compliance with CSPs preferences more than commercial hypervisor. (de Alfonso, Caballer, Calatrava, Moltó, & Blanquer, 2019) introduced a framework that displayed elastic virtual clusters (EVC) executing on elastic physical clusters (EPC). They satisfied user application computing needs and minimized energy consumed. The power management and virtual infrastructure levels were integrated. Then, set an automatic VMC agent reducing power consumption on PMs via live migration. Again, dynamically and transparently changes the memory allocated to VMs thereby fostering an enhanced consolidation. A real dataset is used, which indicated that DCs were able to provide users with the ability to deploy and customized scalable computing clusters while reducing their energy footprint. (Marotta, Avallone, & Kassler, 2018) proposed a fast Simulated Annealing based Resource Consolidation (SARC) algorithm to consider network-related energy consumption, which adds 10-20% of the total energy consumed by IT infrastructure. A novel joint server and network consolidation model were developed. It took account of switches forwarding the traffic and servers hosting the VMs maintaining the QoS. The numerical results demonstrated that the approach was able to save up to 50% of the network-related power consumption as compared with other network unaware approaches. (Ebadi & Jafari Navimipour, 2019) formulated a hybrid metaheuristic algorithm; PSO and Tabu Search (TS). These handled data replicas, energy consumption, performance, cost of creating and maintaining replicas. The efficiency of the approach was validated with PSO, TS and ACO on different tests. The results showed that the hybrid approach outperformed all of the above in terms of energy and cost reduction. (Naseri & Navimipour, 2019) formulated another hybrid optimization approach for service composition in the cloud. They hybridized the Agent-Based Method to purposely compose services by identifying QoS and PSO for selecting the best services based on a fitness function. The method outperformed in terms of reducing the combined resources and waiting time respectively. (Acharya & Demian Antony, 2018) presented a VM allocation strategy that considers VMP by allowing servers' capacity partitioned into classes. These classes are based on RAM and processing abilities matched with VM's need. Then, the matched category is found and provisioned the server for task execution. The experimentation using various DCs scenarios showed that the approach reduces response time and saved energy as compared with traditional VMP. (Wu & Che, 2019) considered to minimized both makespan and total energy consumption. They used Mimetic Differential Evolution (MDE) for assigning jobs to machine and selecting appropriate processing speed level for each job. These were characterized by a job-machine assignment and speed vectors. Also, Adaptive Meta-Lamarckian Learning Strategy (AMLLS), List Scheduling Heuristic, speed adjusting and job-machine heuristics were integrated to enhanced convergence. These strengthen the MDE and outperformed SPEA-II and NSGA-II respectively.

III. EMERGING RESEARCH AREAS IN ENERGY OPTIMIZATION

Despite various research efforts yet energy optimization still remains a challenging issue to DCs due needs in resource utilization. This has necessitated the efforts to find a list of power providers and efficient ways to manage them. Hence, energy is necessary to maintain the working status of all equipment in DCs and its inefficient utilization leads to power wastage. Researchers used dynamic energy reduction techniques; VM migration, frequency, and voltage scaling, power capping/shift, C-states outfitted on processors. Others used load balancing; reducing total execution time ad improvement in response time etc. Yet, research challenges were summarized in a tabular form. This is done to reveal the existing ways, polices to energy-saving using ACS and existing gaps. These, will avail the new researchers to consider and improve on the identified existing research gaps:

S/n	Study	Variant & Tool	System Model	Research Gap(s)
1	(Liu *et al.*, 2016)	(OEM-ACS) – C++ Language	Grouped candidate VMs together thereby reducing the number of active servers	Its application to various cloud sizes with different characteristics.
2	(Duan *et al.*, 2017)	(Improved ACO) – CloudSim	Used prediction model tagged *PreAntPolicy* for scheduling, minimization of energy consumption and	Taking into account the heterogeneous tasks
3	(Shabeera *et al.*, 2017)	(ACO) – CloudSim Extended	Developed a model called *MinDistVMDataPlacement* for VM and Data Placement to reduce cross-network traffic and bandwidth usage. Also, for placing the required number of VMs Data in PMs those are physically closer.	Allocating heterogeneous VMs according to the users' requests, so that the resource utilization can be maximized without deteriorating the job completion time on the allocated VMs.
4	(X. Liu *et al.*, 2017))	(ACO-NoC) - C language	Addressed slow convergence energy efficiency.	Consideration to multi-cores VMP on chip.
5	(X.-F. Liu *et al.*, 2017)	(UACS-DVMP) – ecoCloud	Reduction in the number of migration and hosting of VMs on server using task assignment & reallocation of VM.	Task scheduling & load balancing algorithms were not used.
6	(Moon *et al.*, 2017)	(SACO) - Java	Allocated users' tasks to VM and maximized utilization of server using leading ant avoiding long path called slave ants.	Consideration to heterogeneous clusters and comparison with other greedy approaches
7	(Pang *et al.*, 2017)	(DEMS) – CloudSim	A System for the Management, Load Balancing and Task Scheduling	The use of other bio-computing methods to solve these problems in the DCs.
8	(Pham & Le, 2017)	(MORA-ACS) – CloudSim	Reduced the number of PMs, energy consumption and ensures the performance of DCs	Resource allocation problem for virtual services using dynamic balancing with respect to the VMs migration mechanism.
9	(Tiwari *et al.*, 2017)	(ACO-VMAP) – Graph	Migrated, allocated, placed VMs on top of PMs and reduced energy while leveraging QoS.	Comparison with other algorithms
10	(Moorthy *et al.*, 2017)	(ACO-OVMP) – EclipseIDE	Response time, number of migration, resource wastage and costs are the metrics optimized	Implementation in a real-time environment
11	(Kaewkasi & Chuenmuneewong, 2017)	(ACO) – Go 1.6.2	Distributed Doker containers to host, balanced resources and improved performance	Implementation on other swarm intelligence algorithms
12	(Ashraf & Porres, 2018)	(MODVMC-ACS) - Java	Maximized releasing PMs (P_R) and minimization of the number of VMs migration (nM)	Not dependent on a particular deployment architecture or system model (centralized or otherwise)
13	(Aryania *et al.*, 2018)	(MACS-DVMC) - Java	Reduced active PMs, energy consumption and increase sleeping PMs during migration.	The energy prediction, physical, conceptual and simulation models.
14	(Qin *et al.*, 2018)	(ACS-BVMP), Matlab	Maximized revenue of communication and minimized power consumption	Power minimization with respect to IT equipment and cooling systems.
15	(Hasan *et al.*, 2018)	(ACO_PSO), Java	addressed the problems of mobile CC; prone to error and high energy input demands while guaranteeing minimum SLA violation	Combination with other improved algorithm expectedly to have higher solution
16	(Verma & Tripathi, 2018)	(RBAS), CloudSim	Considered VM allocation and migration	Load reconciliation for VMP

17	(Kanthimathi & Vijayakumar, 2018)	(GA-ACS) CloudAnalyst based on CloudSim	Stabilizes the QoS; response time, cost, throughput, performance and resource utilization	Allocation of optimal resources based on the number of users
18	(Rani & Garg, 2018)	(PA-ACO) Matlab	Reduced power considering parameters; IT equipment and cooling power consumptions	Power minimization due to HDD, RAM size during migration and bandwidth
19	(Prasad Devarasetty & Reddy)	(MOACO) CloudSim	Reduced resource wastage, energy consumption and communication costs	The extension of the functionality of the algorithm to more number of DCs.
20	(Wei *et al.*, 2019)	(AP-ACO) Fat-tree topology	Pursued energy over traffic-aware network and communication cost reductions	Considered dominant CPU consumption as such required further extension and evaluation with real trace data of cloud platform.
21	(Rubaiee & Yildirim, 2019)	(MOACO, WSM, DR & MOORA), Matlab R2010a	Minimized total computation time and energy costs.	A detailed experiment to ascertain if there is a clear pattern between the parameters of the experimental design and objectives.
22	(Farshin & Sharifian, 2019)	(GWO-MACO), Matlab	CPU utilization and memory efficiently for VNFs	Further simulation and implementation in Floodlight or Open Day Light (ODL).
23	(W. Deng *et al.*, 2019)	(ICMPACO) CloudSim	Employed *elites* and *common* ants for balanced convergence speed, solution diversity and improve performance.	The use of other meta-heuristic algorithms
24	(Alharbi *et al.*, 2019)	(ACS-FFD) Java	Reduced total energy consumptions of all active PMs leveraging QoS	Consideration of bandwidth and other power-consuming devices.
25	(Xiao *et al.*, 2019)	(DAVMC-ACS), CloudSim	Reduced energy consumption and migration overhead also controlling the QoS.	Further employment of adaptive threshold at variable workloads for reasonable decisions on VM migration.

Table 1:- Summary of Tools, Variants, policies and Established Research Gaps

The setbacks of various researchers were surveyed and reported in Table 1 The review urged upcoming researchers to adapt, modify, and inject new ideas with a view to addressing these drawbacks in emerging research efforts.

IV. ANALYSIS & DISCUSSION

Performance metrics for energy reduction on frequency and authorship were firstly analyzed as similar to (Bermejo, Juiz, & Guerrero, 2019; Masdari, Nabavi, & Ahmadi, 2016).

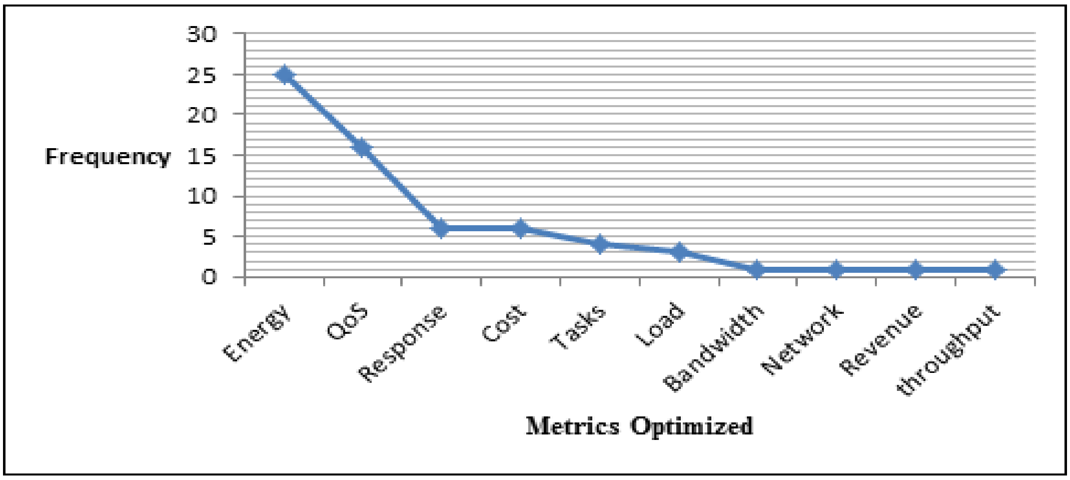

Fig. 1:- Analysis of Metrics Optimized

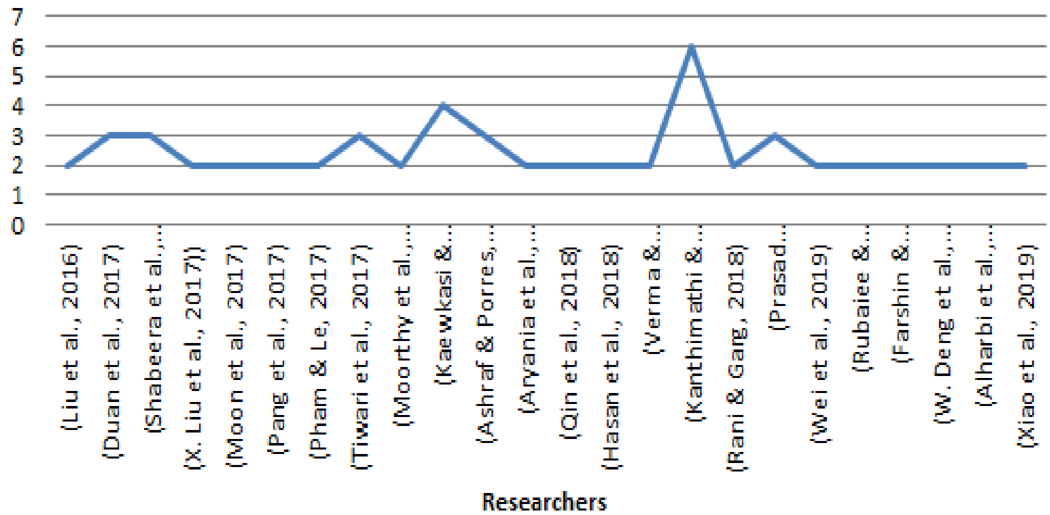

Fig. 2:- No. of Metrics Optimized

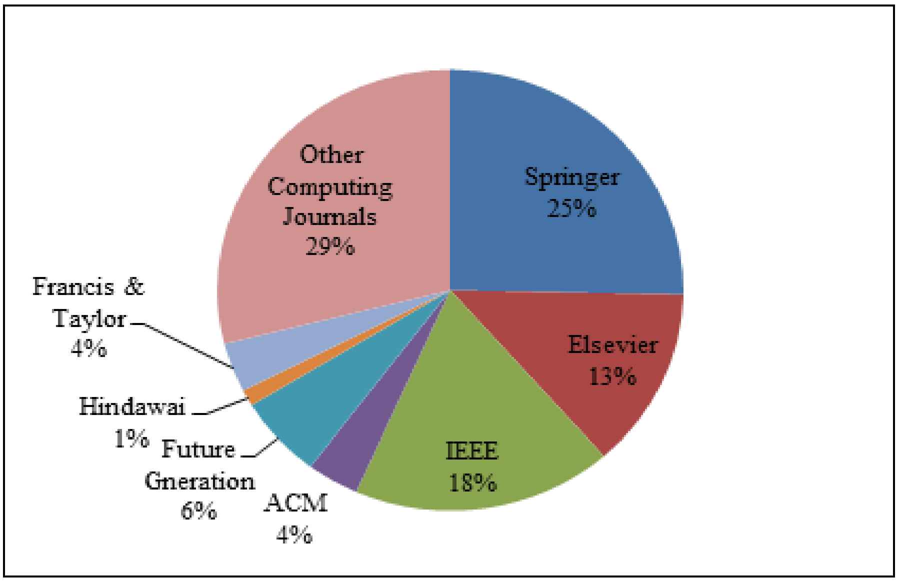

Fig. 3:- Distribution of articles by publishers

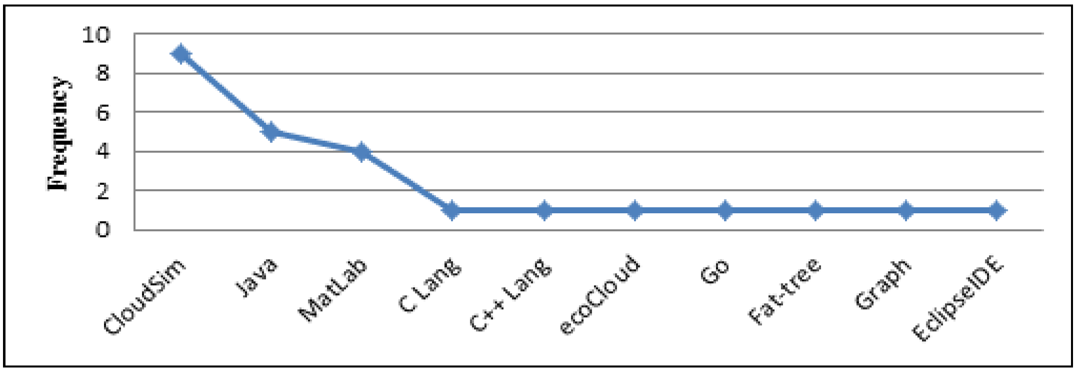

Fig. 4:- Analysis of Simulation Tools

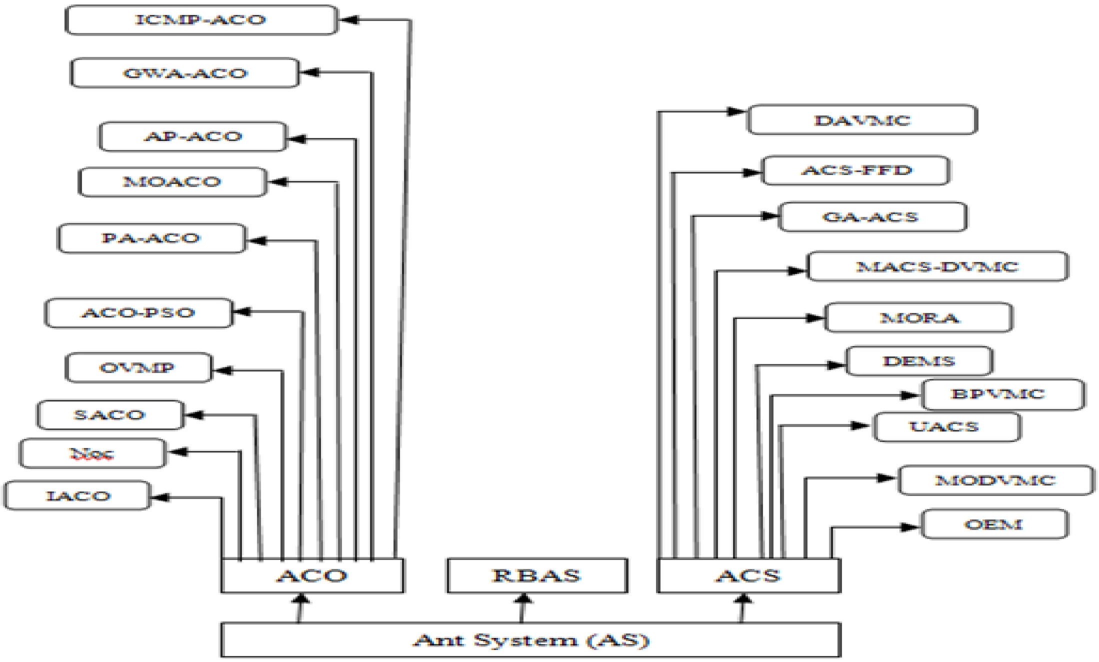

Fig. 5:- Taxonomy of Ant system

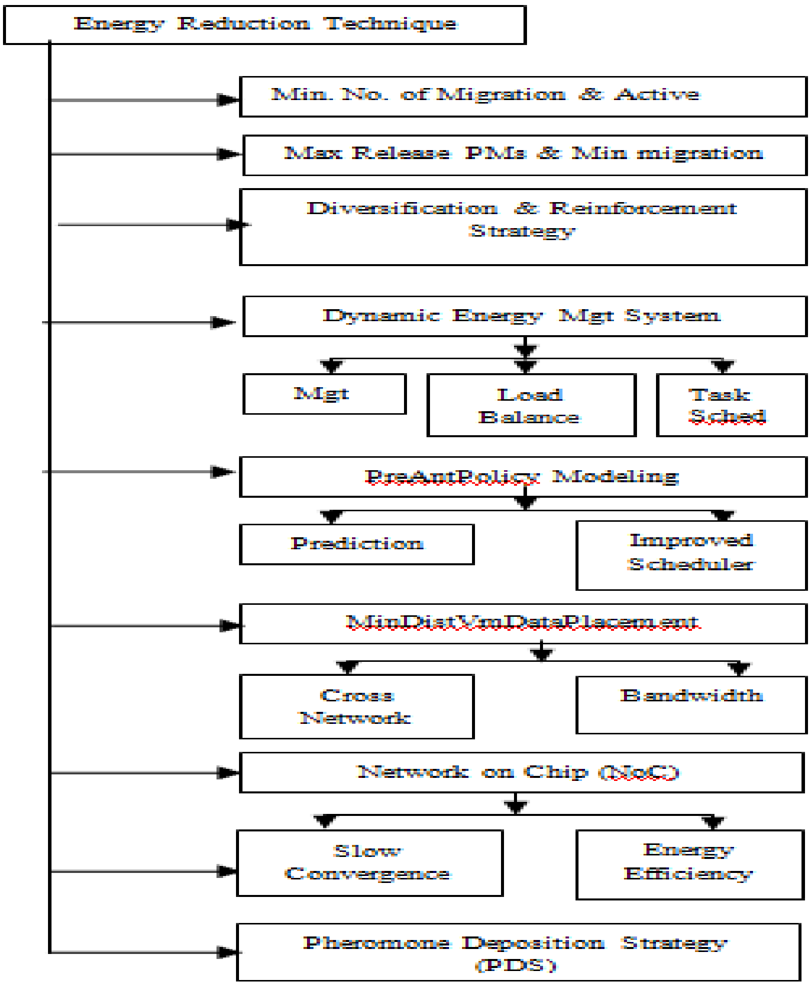

Fig. 6:- ACS's Taxonomy of Energy Reductions (Also, similar to (Khan et al., 2018):

V. CONCLUSION

It has been noted that for almost two decades now, bio-computing remains capable and promising in solving diversified problems. In this review/survey, the worthiness of ACS in particular to energy saving in CC proved efficient. However, other issues remain unresolved leaving other gaps behind for upcoming researchers to accomplish. For instance, fig. 1.1 - 1.2 indicated that VMC's energy reduction strategies are always on the increase using ACS. This further shows the general acceptability of the ACS algorithm in solving many NP-Hard problems. Other novelty of this review, reveals the sources from relevant publishers as indicated in fig. 1.3. Fifty-one (51) consulted articles just for ACS energy-saving strategies were mostly Scopus Index in nature. Also, a suitable decision support tool used were analyzed as contained in fig. 1.4. In the same vein, ACS taxonomy of variants in fig. 1.5 and many proposed ACS-based policies for energy reduction, thus, summarized in a form of taxonomy in fig. 1.6

Conclusively, energy reduction particularly VMC is a promising technology which, researchers proved its successful implementation. Researchers proposed various strategies for effective optimization of resources. This helps CSP to maximize gains and to satisfy customer demands. VMC is an NP-Hard which requires the intervention of biologically inspired algorithms. This may help the computer system solves tasks easily. As such, a promising ACS algorithm is essentially considered for the review. In the future, other nature-inspired algorithms may be considered.

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