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SURVEY OF PARTICLE SWARM OPTIMIZATION ALGORITHM TO OPTIMIZE ENERGY IN MODERN DATA CENTERS

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ABSTRACT

Data centers use a lot of energy, which raises the cost of operation and raises environmental issues. Energy optimization has come a critical aspect of data center operation, and Particle Swarm Optimization (PSO) has surfaced as a well- liked optimization system for minimizing energy consumption. This composition presents a check of PSO and its operation in optimizing energy operation in ultramodern data centers. The paper reviews the being literature on the operation of PSO in data center optimization and highlights the benefits and limitations of PSO compared to other optimization ways. The paper also discusses the challenges of optimizing energy consumption in data centers and how PSO might be used to address these challenges. The paper concludes that PSO is an effective optimization fashion for data center energy optimization and highlights the need for farther exploration to address the remaining challenges.

Keywords: Particle Swarm Optimization, Data Centers, Energy Optimization.

1. INTRODUCTION

Data centers are essential factors of the ultramodern technological world as they give critical support for colorful operations similar as cloud computing, social networking, and e-commerce. Still, data centers use a lot of energy, however, which raises the cost of operation and raises environmental issues. (Goyal etal., 2015) discussed that cloud computing provides mileage- acquainted IT services but consumes significant energy, which has high cost and environmental impact. Data center energy optimization is a complex problem due to the large number of variables involved, similar as the workload demands, temperature, moisture, and power consumption of the colorful factors. Traditional approaches to energy optimization in data centers have reckoned on simple heuristic rules and heuristics, similar as conforming the temperature setpoints or turning off idle waiters. Still, these approaches frequently affect in sour energy effectiveness and can compromise the SLAs of the data center. Energy optimization has come a pivotal aspect of data center operation, and optimization styles like Particle Swarm Optimization (PSO) are presently being developed to minimize energy consumption. (Jiang et al., 2014) discussed about PSO is a population-based optimization algorithm that was developed based on the social behavior of birds flocking or fish schooling. In PSO, particles are initialized with random positions and velocities, and each particle evaluates its fitness based on a given objective function. Using both its own optimal location and the optimal position of the swarm, the particle then adjusts its position and velocity. Until a halting requirement is satisfied, the algorithm repeatedly changes the positions and speeds of the particles. PSO has been demonstrated to be successful in resolving optimization issues, such as reducing data center energy use.

PSO has several advantages that make it a suitable optimization algorithm for data center energy optimization. Originally, PSO is a population- grounded optimization fashion, which means it can explore multiple results together. This is particularly useful in complex optimization problems where there are multiple original optima. Secondly, PSO is easy to apply and requires minimum parameter tuning, making it a suitable optimization fashion for data center drivers who may not have a background in optimization algorithms. PSO has been applied to colorful aspects of data center operation, including workload scheduling, virtual machine (VM) placement, and server connection. In workload scheduling, PSO can be used to optimize the allocation of workloads to servers grounded on their energy consumption and performance characteristics. In VM placement, PSO can be used to place VMs on physical servers in a way that minimizes energy consumption while icing that performance conditions are met. PSO has also been used for server connection, where underutilized servers are turned off or consolidated to reduce energy consumption.

Optimizing energy use in data centers is crucial as it reduces operational costs and mitigates the environmental effect of data centers as provided an impression by (Aruna et al., 2015). In recent years, PSO has become more well-liked recently for reducing energy usage in data centers. PSO has been applied to optimize various aspects of data center management, including workload scheduling, virtual machine (VM) placement, and server consolidation. Data centers must become more environmentally friendly and energy efficient as the Internet expands. Evaluation measures has been evaluated to assess energy efficiency in data centers, with factors such as site selection, IT equipment, and cooling systems considered. Current metrics are valuable but more comprehensive and multi-scale metrics are needed to achieve carbon neutrality. Sustainability should be prioritized in selecting metrics as discussed by (Selvan et al., 2019).

Challenges of Optimizing Energy Consumption in Data Centers:
Reducing energy utilization in data centers is challenging due to several factors, including the large search space, the need to balance energy consumption and performance, and the unpredictable nature of data center workloads. Data centers typically have a large number of physical servers, virtual machines, and workloads, resulting in a large search space that can make optimization challenging. Furthermore, energy usage must be reduced without affecting the efficiency of the servers' operating programmes. This requires a multi-objective optimization approach that considers both energy consumption and performance metrics such as response time and throughput. Furthermore, data center workloads are dynamic and vary over time requiring optimization techniques that can adapt to changing conditions. Large virtualized data centers have been established as a result of the rise in processing demand caused by contemporary service applications and the move to cloud computing. However, these data centers use a lot of energy, which drives up operating costs and produces carbon emissions.

Making IT resources more greener and reducing operational costs are the main goals of the key research area known as "green cloud computing." (Patel et al., 2015) focused on different Green IT application areas of Green IT are reviewed, and research issues, objectives, and concerns related to Green IT areas are elaborated through comparative analysis. Green Computing is required in today's world of remote data centers and cloud computing to guarantee economic dependability and energy efficiency. The challenge lies in lowering the energy usage of data centers as data continues to grow rapidly. Green Cloud computing aims to address issues related to infrastructure for computations, minimizing energy consumption while making cloud facilities dependable and economically productive.
Applications of Particle Swarm Optimization in Data Center Optimization:

PSO has been applied to colorful optimization problems in data centers, including workload scheduling, resource allocation, cooling system optimization, and power operation. Workload scheduling is the process of assigning computing resources to different tasks in a data center to optimize the overall performance. PSO has been used to optimize workload scheduling in data centers by minimizing the energy consumption and maximizing the system outturn. Resource allocation is the process of assigning computing resources similar as CPU, memory, and storage to different operations or users. PSO has been applied to optimize resource allocation in data centers by minimizing the energy consumption and maximizing the resource application. Cooling system optimization is the process of optimizing the cooling structure of a data center to minimize the energy consumption and maintain the optimal temperature. PSO has been used to optimize the cooling system of data centers by minimizing the energy consumption and maximizing the cooling effectiveness. Power operation is the process of managing the power consumption of data center outfit similar as servers, storage bias, and networking outfit. PSO has been applied to optimize the power operation of data centers by minimizing the energy consumption and maintaining the Quality of Service (QoS). The purpose of this paper is to present a check of PSO algorithm and its operation in optimizing the use of energy in ultramodern data centers. The paper will emphasize the difficulties in reducing energy use in data centers and how PSO could be used to address these challenges. Also, the paper will review the being literature on the operation of PSO in data center optimization and punctuate the benefits and limitations of PSO compared to other optimization ways.

2. LITERATURE REVIEW

The study by (Pang et al., 2017) looks on variable energy planning for cloud data centers that are power-efficient. The stated task-driven resource allocation strategy outperforms the ACO, Min-Min, and RR scheduling algorithms with regard to system running time and energy usage. The one recommended can match the performance standards while preserving up to 28–40% energy. (Vijayakumar et al., 2020) proposes a modified PSO algorithm to optimize economic load dispatch for lowering the cost of producing electricity and conserve energy resources. The novel interdependence strategy balances the regional search ability and universal optimization. The introduction of many swarms allows for effective optimization. In terms of the lowest cost of electricity generation and the load dispatch problem, the suggested algorithm performs better than ABC, GAs, and traditional PSO algorithms. For efficiency evaluation, real-world examples can be used to assess the algorithm.

The study suggests a virtual machine allocation mechanism that uses less energy to lower energy usage in cloud data centers as provided by (Xiong et al., 2014). The PSO method and the energy-efficient multi-resource allocation model are the foundations of the algorithm. To find the sweet spot between resource use and energy consumption, the fitness function is defined as the total Euclidean distance. The suggested approach performs better than the established heuristic algorithms, MBFD and MBFH, because it uses less energy and makes acceptable use of the system resources. To lower cloud computing's energy usage, this study by (Shao et al., 2022) suggests a distributed Locust-inspired scheduling algorithm (LACE). Based on locust-derived behavior, LACE optimizes the allocation of virtual machines and distributes scheduling among servers. The algorithm's ability to reduce energy consumption while still achieving performance requirements was evaluated in comparison to existing scheduling methods. The research also suggests a resource provisioning and scheduling method utilizing the Superior Element Multitude Optimization algorithm for scientific workflows on IaaS and PaaS clouds.

The Energy Efficient Particle Swarm Optimization (EE-PSO) Algorithm was developed by researchers to consolidate containers into the fewest possible hosts and VMs while preserving performance levels in cloud data centres as discussed by (Dandah et al., 2022). Experimental evaluations utilizing the ContainerCloudSim toolkit confirmed that the approach beat competing works in terms of energy usage, QoS guarantees, number of newly created VMs, and number of container migrations. In order to optimize job distribution in mobile cloud systems, this research by (Mateo et al., 2017) suggests a Particle Swarm Optimization (PSO)-based offloading technique. Prior to implementing PSO, tasks are categorized using K-means clustering to reduce the amount of particles and choose the ideal data center for a certain task. Although it requires a little more processing time than other methods, the suggested PSO excels at selecting data centers with regard to energy consumption.

This study by (Okoye et al., 2018) looks into how much energy is used in data centers and suggests a useful approach for reducing excessive energy demand and projection. Results from the simulation show significant energy management without sacrificing service quality. The population-based stochastic optimization algorithm known as Particle Swarm Optimization (PSO), which was inspired by the swarm behavior of animals, is introduced in this study. It covers the history and background of PSO, analyses its current state in terms of both research and applications, covering a variety of variants and engineering applications, and identifies difficulties that still need to be solved as well as potential future research areas as discussed by (Wang et al., 2017).

The difficulty of reducing energy consumption in a virtualized data center while meeting resource demands is covered in the article. To solve the optimization challenge, (Wang et al., 2013) suggest employing particle swarm optimization (PSO), which they suggest using with improved parameters and operators, an energy-aware local fitness first approach, and a brand-new coding scheme. According to the data, their method performs better than others and can cut energy use by 13% to 23%. This article by (Buyya et al., 2010) suggests energy-efficient management strategies for cloud computing, including design concepts, resource allocation rules, and scheduling formulas that take into account power usage and quality-of-service requirements. Additionally, a revolutionary software technology is suggested. Under dynamic workload situations, performance assessments using the CloudSim toolbox demonstrate the potential for considerable performance and cost improvements.

This article by (Beloglazov et al., 2012) suggests energy-efficient management strategies for cloud computing, including design concepts, resource allocation rules, and scheduling formulas that take into account power usage and quality-of-service requirements. Additionally, a revolutionary software technology is suggested. Under dynamic

workload situations, performance assessments using the CloudSim toolbox demonstrate the potential for considerable performance and cost improvements. In order to maximize resource usage and maintain Service Level Agreements (SLAs) for quality of service, this study by (Beloglazov et al., 2010) suggests a method for dynamic consolidation of virtual machines (VMs) utilizing adaptive utilization thresholds. Utilizing workload traces from PlanetLab servers, the suggested technique is validated and shown to be effective for a variety of workloads.
(He et al., 2021) present an optimization strategy for reducing energy consumption in data center cooling systems using an integrated heat pipe cooling system. A heat transfer and energy consumption model was established to analyze the relationship between operating parameters and energy efficiency. The proposed energy efficiency optimization strategy was verified through experiments, and the results showed significant improvements in the energy efficiency ratio of the cooling system in natural and integrated cooling modes. The study also analyzed the energy-saving effects of the system in different climate cities. The growing electricity consumption of data centers has led to efforts to improve energy efficiency. Virtual machine consolidation, implemented through virtual machine placement, is one solution. This paper by (Wu et al., 2012) proposes a Simulated Annealing algorithm to further improve placement, achieving energy savings up to 25% compared to the First Fit Decreasing algorithm in an acceptable time frame.

This paper by (Ma et al., 2022) proposes a new energy consumption evaluation method for cloud computing data centers, which includes building an evaluation model, using multiple linear and nonlinear regression models to analyze the correlation between independent and dependent variables, introducing deep learning mechanisms, and obtaining regression parameters through iterative training. The results show that this method has small and stable energy consumption deviation, reduces the relative error of evaluation power change, and lowers the evaluation training loss. (Li et al., 2012) addresses the need to save energy consumption and reduce emissions in data centers by implementing online dynamic scheduling of computational and physical resources. The paper proposes a layered algorithm for scheduling data center resources and establishes energy-consumption models using tractable approximations. The paper also establishes dynamic scheduling models and learning-based algorithms for large-size heterogeneous resources. Simulation experiments using EnergyPlus and GreenCloud software show the efficiency of the model and algorithm.

3. COMPARATIVE STYUDY

There are several other optimization algorithms that have been used for data center energy optimization, including genetic algorithms (GA), ant colony optimization (ACO) simulated annealing (SA), Dynamic Programming (DP) and Reinforcement Learning (RL). In this portion, we will differentiate the PSO algorithm with these other algorithms based on several criteria.

PSO vs Genetic Algorithms (GA):
PSO is a Swarm-based optimization algorithm whereas GA is Population-based. PSO has a faster convergence speed than GA and also it provides a high quality of solution whereas in GA the quality of solution is high in only some cases. PSO is a robust algorithm but GA is affected by noise. Implementation of PSO is easier as compared to GA and also PSO provides us with more scalability than GA. PSO is more capable than GA in handling dynamic changes in energy demands. Both these algorithms have ability to incorporate renewable energy sources. Although GA is more suitable for large-scale data centers but PSO requires less computational resources.

PSO vs Ant Colony Optimization (ACO):
ACO is Ant-based optimization algorithm. ACO has a slower convergence speed than PSO and also PSO provides a high quality of solution whereas in ACO the quality of solution is moderate. PSO is a robust algorithm but ACO is affected by pheromone trail. Implementation of PSO is easier as compared to ACO and also PSO provides us with more scalability than ACO. Both PSO and GA are capable in handling dynamic changes in energy demands. Only PAO has ability to incorporate renewable energy sources. ACO and PSO both are similar in terms of suitability for large-scale data centers and computational resources.

PSO vs Simulated Annealing (SA):
Simulated Annealing (SA) uses a probabilistic approach. Even this algorithm cannot beat PSO in terms of convergence speed and quality of solution. Similar to GA this algorithm is also affected by noise. Implementation of SA is more complex than PSO, GA and ACO. PSO is more scalable than SA but SA is similar to ACO and GA in terms of

scalability. PSO has the ability to optimize energy usage of individual components such as servers, cooling, etc. but SA lacks this quality and also SA cannot incorporate renewable energy sources.

PSO vs Dynamic Programming (DP):
Dynamic Programming uses a mathematical approach and has the ability to optimize energy consumption. DP cannot handle dynamic changes in energy demands and also is incapable to optimize energy usage of individual components. Both PSO and DP can optimize energy at real-time short-term and long-time. DP is not suitable for large scale data centers but used less computational resources. DP is not capable to incorporate renewable energy resources.

PSO vs Reinforcement Learning (RL):
Reinforcement Learning (RL) uses trial and error approach. RL performs better in energy optimization, handling dynamic energy demand changes, optimizing energy of individual components (i.e. servers, coolers, etc.). RL has ability to optimize energy at different time scales, incorporate renewable energy resources, handling temperature workload. Reinforcement Learning is better than PSO in terms of suitability for large-scale data centers as well as ability to learn from data and adapt accordingly although, implementation of PSO is easier than RL.

4. CONCLUSION

PSO is an effective optimization technique for data center energy optimization, offering several advantages over other optimization techniques. This paper provided a survey of PSO and its application in optimizing energy usage in modern data centers. The paper reviewed the existing literature on the application of PSO in data center optimization and highlighted the benefits and limitations of PSO compared to other optimization techniques. The paper also discussed the difficulties of maximizing energy consumption in data centers and how PSO can be used to address these challenges. Also by observing the above tables we come to the conclusion that PSO algorithm have greater impact in data center energy optimization. PSO algorithm has performed better when compared to other algorithm in various parameters. This study is going to be helpful for other researchers who further want to dig deep into this topic. This study provides perception into the advantages and disadvantages of different energy optimization algorithms. Apart from other advantages researchers can also select most effective algorithm according to their requirements. Further research is needed to address the remaining challenges and to develop customized PSO variants that are tailored to specific data center scenarios.

REFERENCES

Aruna, P. & Vasantha S. (2015). A Particle Swarm Optimization Algorithm for Power-aware Virtual Machine Allocation. *IEEE 6th ICCCNT - 2015 July 13 - 15, 2015, Denton, U.S.A.* doi:10.1109/ICCCNT.2015.7395196.

Beloglazov, Abawajy, A.,J. & Buyya, R. (2012). Energy-aware resource allocation heuristics for effcient management of data centers for cloud computing. *Future Generation Computer Systems*, 28(5), 755-768,2012. doi:10.1016/j.future.2011.04.017.

Beloglazov, A. and Buyya, R. (2010). Adaptive Threshold- Based Approaches for Energy-Effcient consolidation of VMs in Cloud Data Center. *Proceedings of the 81h International Workshop on Middleware for Grids, Clouds and e-Sceince, Article 4, ACM*. doi:https://doi.org/10.1145/1890799.1890803.

Buyya, R., Beloglazov, A. & Jemal Abawajy (2010). Energy-Efficient Management of Data Center Resources for Cloud Computing: A Vision, Architectural Elements, and Open Challenges. https://www.researchgate.net/publication/45921163_Energy

Dandah, R. S.,Kabalan, K. & Rajab, H. (2012). A Host Selection Algorithm for Dynamic Container Consolidation in Cloud Data Centres using Particle Swarm Optimization. *International Research Journal of Engineering and Technology (IRJET)*, 09(03).

Goyal, A. & Chahal, N.S. (2015). A Proposed Approach for Efficient Energy Utilization in Cloud Data Center. *International Journal of Computer Applications (0975 – 8887), 115 (11)*. doi: 10.5120/20197-2439.

He, Z., Xi, H., Ding, T., Wang, J. & Li, Z. (2021). Energy Efficiency Optimization of an Integrated Heat Pipe Cooling System in Data Center Based on Genetic Algorithm. *Applied Thermal Engineering, 182(5).* doi:10.1016/j.applthermaleng.2020.115800.

Jiang,W., Zhang, Y. & Wang, R. (2014). Comparative Study on Several PSO Algorithms. *2014 26th Chinese Control and Decision Conference.* doi:10.1109/CCDC.2014.6852332.

Li, X., Nie, L. & Chen S. (2012). Approximate Dynamic Programming Based Data Center Resource Dynamic Scheduling for Energy Optimization. *2012 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*. doi:10.1109/iThings.2014.87.

Ma, H. & Ding, A. (2022). Method for evaluation on energy consumption of cloud computing data center based on deep reinforcement learning. *Electric Power Systems Research, 208*. doi: https://doi.org/10.1016/j.epsr.2022.107899.

Mateo, J.C.A. & Lee J. (2017). A Task Offloading Approach using Classification and Particle Swarm Optimization. *Journal of Internet Computing and Services(JICS) 2017*. doi:0.7472/jksii.2017.18.1.01.

Okoye, F., Asogwa, T. & Ozor G. (2018). Optimization of Energy Consumption for Data Center. *Journal of Scientific and Engineering Research*.

Pang, S., Zhang, W., Ma, T. & Gao Q. (2017). Ant Colony Optimization Algorithm to Dynamic Energy Management in Cloud Data Center. *Hindawi Mathematical Problems in Engineering, Article ID 4810514*. doi:https://doi.org/10.1155/2017/4810514.

Patel, Y.S., Mehrotra, N. & Soner S. (2015). Green Cloud Computing: A Review on Green IT Areas for Cloud Computing Environment. *1st International Conference on Futuristic trend in Computational Analysis and Knowledge Management (ABLAZE-2015)*. doi:10.1109/ABLAZE.2015.7155006.

Selvan, C.T., Santhoshkumar, M., Santhoshkumar, R.M. & Sasidharan S. (2019). Improve Energy Consumption Model for Cloud Data Centers using PSO Algorithm. *International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Published by, www.ijert.org RTICCT - 2019 Conference Proceedings*. doi:10.17577/IJERTCONV7IS01035.

Shao, X., Zhang, Z., Song, P., Feng, Y. & Wang X. (2022). A review of energy efficiency evaluation metrics for data centers. 271, https://doi.org/10.1016/j.enbuild.2022.112308. doi:https://doi.org/10.1016/j.enbuild.2022. 112308.

Vijayakumar, T. & Vinothkanna R. (2020). Efficient Energy Load Distribution Model using Modified Particle Swarm Optimization Algorithm. *Journal of Artificial Intelligence and Capsule Networks*, 02(04), 226-231. doi:10.36548/jaicn.2020.4.005.

Wang, D., Tan, D. & Liu L. (2017). Particle swarm optimization algorithm: an overview. *Springer-Verlag Berlin Heidelberg* . doi:10.1007/s00500-016-2474-6.

Wang, S., Liu, Z., Zheng, Z., Sun, Q. & Yang F. (2013). Particle Swarm Optimization for Energy-Aware Virtual Machine Placement Optimization in Virtualized Data Centers. *19th IEEE International Conference on Parallel and Distributed Systems*. doi:10.1109/ICPADS.2013.26.

Wu, Y., Tang M. & Fraser W. (2012). A Simulated Annealing Algorithm for Energy Efficient Virtual Machine Placement. *IEEE International Conference on Systems, Man, and Cybernetics October*, 14-17, COEX, Seoul, *Korea*. doi:10.1109/ICSMC.2012.6377903.

Xiong, A., Xu, C.H. (2014). Energy Efficient Multiresource Allocation of Virtual Machine Based on PSO in Cloud Data Center. *Hindawi Publishing Corporation Mathematical Problems in Engineering, ID 816518*. doi:10.1155/2014/816518.