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# SLA-Aware Energy Efficient Resource Management for Cloud Environments

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**ABSTRACT** Cloud computing provides online services to customers using pay as you go model. The Cloud computing enables customers to outsource the large and complex tasks to the cloud data centers for the execution and result generations. Cloud data centers host the incoming tasks by providing resources, such as CPU, RAM, storage, and bandwidth. As the large data centers provide the basic resources to hosted tasks, they also consume a huge amount of energy, which leads to higher operating cost and CO<sub>2</sub> traces. Therefore, research community felt the need to provide energy-efficient solutions that reduce the impact of the aforementioned issues. Consequently, researchers proposed many solutions, and majority of them are based upon the concept of consolidation. Consolidation techniques place the incoming tasks on minimum possible servers, thus increasing the resource utilization and decreasing energy consumption. In this paper, we use the same workload consolidation concept and present two techniques that reduce energy consumption while ensuring the negotiated quality-of-service. Moreover, we enhanced two existing techniques by improving the energy efficiency and introducing service level agreement (SLA) awareness to minimize the overall SLA violations. Performance evaluation of the proposed techniques is done based on fluctuating workloads, and results show that our techniques outperform existing techniques in terms of energy efficiency, SLA compliance, and performance assurance at the network level. Moreover, correctness of the proposed techniques is demonstrated by modeling and verifying them with the help of high-level Petri Nets, SMT-Lib, and Z3 solver.

**INDEX TERMS** Cloud computing, energy efficiency, resource management, resource allocation, SLA awareness.

## I. INTRODUCTION

Cloud computing is emerging as one of the popular solutions for on-demand and dynamic resource provisioning [1]. The provisioning and maintenance of cloud resources are done with the help of resource management (RM) techniques [2], [3]. RM techniques are responsible to keep the track of free resources and assign the resources from the free pool to incoming tasks. Along with certain advantages, RM techniques introduce a set of research challenges that need to be addressed. One of the key research challenges in RM is the energy efficiency, and researchers are focusing on this challenge [4]–[6]. Energy efficiency not only minimizes the overall the expenditure of the cloud data centers (DCs), but also have a positive effect on environment [7], [8]. CO<sub>2</sub> and Green House Gases (GHG) play an important role in environmental pollution [12]–[14], and reports published in 2007 highlight the fact that Information and

Communication Technology (ICT) industry produced about 2% of total CO<sub>2</sub> emissions. Moreover, recent report predicts that the CO<sub>2</sub> emissions of ICT industry will increase to 12% by 2020 [15]. On the other hand, big ICT companies like Google are already hosting hundred and thousands of servers and in 2010 these companies consumed about 271.8 billion kWh electricity [9], [10]. Furthermore, recent reports suggest that the energy consumption of ICT industry will grow to about 1963 billion kWh in 2020 [11].

In computational DCs, servers are considered as key energy consumers. Servers consume about 80% of the total energy, whereas, the rest of 20% is consumed by networking and storage devices [16]. The main reason for the aforementioned fact is the frequent use of servers for hosting and computing of users' tasks. Recently, researchers have proposed various energy-efficient solutions that tend to reduce energy consumption at the server level [17]. The proposed solutions

# Sla Based Energy Efficient Resource Management In Cloud

**Albert Y. Zomaya, Young Choon Lee**



## **Sla Based Energy Efficient Resource Management In Cloud:**

Next-Gen Computing and Communication Systems Arun K. Somani, Deepti Mishra, Manju Khari, Pramod Gaur, Muhammad Arsalan, 2026-01-01 This book constitutes the refereed proceedings of the First International Conference on Next Gen Computing and Communication Systems ICNCS 2025 held in Jaipur India during April 18 19 2025 The 8 full papers presented in this volume were carefully reviewed and selected from 134 submissions They are organized into the following topical sections Next Gen Computing Next Gen Networking and Communication Systems and Emerging Applications and Use Cases *Operationalizing Multi-Cloud Environments* Rajganesh Nagarajan, Pethuru Raj, Ramkumar

Thirunavukarasu, 2021-09-17 This book discusses various aspects of the multi cloud paradigm The initial portion of the book focuses on the motivations for the industry to embrace a multi cloud option and the distinct business technology and user cases of multi cloud implementations The middle part of the book explains the challenges of setting up and sustaining multi cloud environments The latter portion focuses on the next generation technologies and tools along with multi cloud platforms processes patterns and practices The final segment of the book is dedicated for cloud brokerage systems The various traits and tenets of cloud brokerage services especially for accomplishing cloud intermediation integration orchestration governance security management configuration etc are explained in detail The book also clearly articulates how to have intelligent brokers **Data Science and Intelligent Applications** Ketan Kotecha, Vincenzo Piuri, Hetalkumar N.

Shah, Rajan Patel, 2020-06-17 This book includes selected papers from the International Conference on Data Science and Intelligent Applications ICDSIA 2020 hosted by Gandhinagar Institute of Technology GIT Gujarat India on January 24 25 2020 The proceedings present original and high quality contributions on theory and practice concerning emerging technologies in the areas of data science and intelligent applications The conference provides a forum for researchers from academia and industry to present and share their ideas views and results while also helping them approach the challenges of technological advancements from different viewpoints The contributions cover a broad range of topics including collective intelligence intelligent systems IoT fuzzy systems Bayesian networks ant colony optimization data privacy and security data mining data warehousing big data analytics cloud computing natural language processing swarm intelligence speech processing machine learning and deep learning and intelligent applications and systems Helping strengthen the links between academia and industry the book offers a valuable resource for instructors students industry practitioners engineers managers researchers and scientists alike Proceedings of the International Conference on Soft Computing Systems L. Padma Suresh, Bijaya

Ketan Panigrahi, 2015-12-07 The book is a collection of high quality peer reviewed research papers presented in International Conference on Soft Computing Systems ICSCS 2015 held at Noorul Islam Centre for Higher Education Chennai India These research papers provide the latest developments in the emerging areas of Soft Computing in Engineering and Technology The book is organized in two volumes and discusses a wide variety of industrial engineering and scientific applications of the

emerging techniques It presents invited papers from the inventors originators of new applications and advanced technologies

*New Frontiers in Cloud Computing and Internet of Things* Rajkumar Buyya,Lalit Garg,Giancarlo Fortino,Sanjay Misra,2022-09-26 This book provides an account of the latest developments in IoT and cloud computing and their practical applications in various industrial scientific business education and government domains The book covers the advanced research and state of the art review of the latest developments in IoT and cloud computing and how they might be employed post COVID era The book also identifies challenges and their solutions in this era shaping the direction for future research and offering emerging topics to investigate further The book serves as a reference for a broader audience such as researchers application designers solution architects teachers graduate students enthusiasts practitioners IT managers decision makers and policymakers The book editors are pioneers in the fields of IoT and Cloud computing Provides an account of the latest developments in IoT and cloud computing and how it can aid in a COVID 19 Era in a variety of applications Identifies IoT and cloud computing challenges and their solutions shaping the direction for future research Serves as a reference for researchers application designers solution architects teachers and graduate students

Proceedings of the Second International Conference on Soft Computing for Problem Solving (SocProS 2012), December 28-30, 2012 B. V. Babu,Atulya Nagar,Kusum Deep,Millie Pant,Jagdish Chand Bansal,Kanad Ray,Umesh Gupta,2014-07-08 The present book is based on the research papers presented in the International Conference on Soft Computing for Problem Solving SocProS 2012 held at JK LakshmiPat University Jaipur India This book provides the latest developments in the area of soft computing and covers a variety of topics including mathematical modeling image processing optimization swarm intelligence evolutionary algorithms fuzzy logic neural networks forecasting data mining etc The objective of the book is to familiarize the reader with the latest scientific developments that are taking place in various fields and the latest sophisticated problem solving tools that are being developed to deal with the complex and intricate problems that are otherwise difficult to solve by the usual and traditional methods The book is directed to the researchers and scientists engaged in various fields of Science and Technology

**Proceedings of the 5th International Conference on Frontiers in Intelligent Computing: Theory and Applications** Suresh Chandra Satapathy,Vikrant Bhateja,Siba K. Udgata,Prasant Kumar Pattnaik,2017-03-15 The book is a collection of high quality peer reviewed research papers presented at International Conference on Frontiers of Intelligent Computing Theory and applications FICTA 2016 held at School of Computer Engineering KIIT University Bhubaneswar India during 16 17 September 2016 The book presents theories methodologies new ideas experiences and applications in all areas of intelligent computing and its applications to various engineering disciplines like computer science electronics electrical and mechanical engineering

**Applications of Machine Learning in Big-Data Analytics and Cloud Computing** Subhendu Kumar Pani,Somanath Tripathy,George Jandieri,Sumit Kundu,Talal Ashraf Butt,2022-09-01 Cloud Computing and Big Data technologies have become the new descriptors of the

digital age The global amount of digital data has increased more than nine times in volume in just five years and by 2030 its volume may reach a staggering 65 trillion gigabytes This explosion of data has led to opportunities and transformation in various areas such as healthcare enterprises industrial manufacturing and transportation New Cloud Computing and Big Data tools endow researchers and analysts with novel techniques and opportunities to collect manage and analyze the vast quantities of data In Cloud and Big Data Analytics the two areas of Swarm Intelligence and Deep Learning are a developing type of Machine Learning techniques that show enormous potential for solving complex business problems Deep Learning enables computers to analyze large quantities of unstructured and binary data and to deduce relationships without requiring specific models or programming instructions This book introduces the state of the art trends and advances in the use of Machine Learning in Cloud and Big Data Analytics The book will serve as a reference for Data Scientists systems architects developers new researchers and graduate level students in Computer and Data science The book will describe the concepts necessary to understand current Machine Learning issues challenges and possible solutions as well as upcoming trends in Big Data Analytics

**Energy-efficient Resource Management Framework for Cloud Data Centers** Khulekani Sibiya,2022 [Algorithms for Energy Efficient Load Balancing in Cloud Environments](#) Norman Peitek,2014-12-30 Seminar paper from the year 2013 in the subject Computer Science Commercial Information Technology grade 1 0 Otto von Guericke University Magdeburg Faculty of Computer Science course Recent Topics in Business Informatics language English abstract Energy efficiency has a rising importance throughout society With the growth of large data centers the energy consumption becomes centralized and nowadays takes a significant amount of the overall electricity consumption of a country Load balancing algorithms are able to make an existing infrastructure more efficient without major drawbacks This structured literature research presents the state of the art technology regarding the load balancing approach to make data centers more energy efficient The state of the art approaches are reviewed for techniques improvements and consideration of performance effects

*Resource Management in Cloud Computing* Sakshi Patni,Deepika Saxena,Ashutosh Kumar Singh,2025-02-10 This book addresses fundamental concepts and practical implementations in cloud computing environments focusing on load balancing and resource management As cloud computing's popularity grows expertise in infrastructure management is crucial for delivering flawless subscription based services and hosted data solutions The book presents novel models for cloud resource management to improve operational efficiency through better virtual machine VM placements Beginning with task scheduling and resource allocation basics the book progresses to resource management concepts It introduces innovative models for dynamic resource allocation heuristic approaches for optimal host selection secure resource management frameworks multi objective VM allocation schemes and data security models A significant contribution is an effective model integrating load balancing resource management Quality of Service QoS security and cloud performance for Infrastructure as a Service IaaS The book offers innovative methodologies for dynamic resource allocation

and service administration in cloud datacenters It presents traffic management techniques to reduce energy consumption improve resource utilization and enhance security through optimized VM placement with experimental validation These models improve response time throughput resource utilization energy consumption and failure node management Security is addressed through secure VM placement strategies making it harder for attackers to achieve co tenancy A multi objective approach for secure load balancing optimizes multiple conflicting objectives simultaneously The book includes cyber threat countermeasures and provides recommendations for organizations and users Suitable for senior undergraduate and graduate courses in cloud computing resource allocation security and energy consumption methods the book includes examples and tutorials using Cloudsim tools for beginners This helps them understand virtual infrastructure and service design The methodologies benefit both cloud service providers and customers offering cost effective solutions for revenue maximization The comprehensive approach makes the book valuable for academic study and practical application in cloud computing environments

**Energy-Efficient Resource Management Techniques for Cloud Data Centers** Mehdiar Dabbagh, 2016

Energy consumption has become a great deal for cloud service providers due to financial as well as environmental concerns Studies show that cloud servers operate most of the time at only between 10% and 50% of their maximal utilizations These same studies also show that servers that are kept ON but are idle or lightly utilized consume significant amounts of energy In this thesis we develop new resource management techniques that enable automated energy efficient allocation of cloud data center resources thereby reducing energy consumption and hence cutting down on the electricity bills of service providers Specifically our developed techniques consist of the following four complimentary frameworks

- 1 Workload Prediction Framework It predicts the number of Virtual Machine VM requests along with their amounts of CPU and memory resources using k Means clustering and adaptive Wiener filter prediction techniques This proposed prediction framework provides accurate estimations of the number of needed servers thus reducing energy consumption by putting to sleep unneeded servers
- 2 Resource Scheduling Framework It reduces the time during which servers are kept ON by placing VMs with similar completion times on the same server while allocating more resources to the VMs that need more time to accomplish their tasks The framework also allocates more resources for the delay sensitive tasks whose charging cost is dependent on how fast they accomplish so that they finish earlier which generates higher revenues This is all done by solving a convex optimization problem that guarantees that all the scheduled tasks meet their hard deadlines
- 3 Resource Overcommitment Framework It consolidates data center workloads on as few ON servers as possible by assigning VMs to a server in excess of its real capacity anticipating that each assigned VM will only utilize a part of its requested resources The framework first determines the amount of server resources that can be overcommitted by predicting the future resource demands of admitted VMs It then handles server overloads by predicting them before occurring and migrating VMs from overloaded servers to other under utilized or idle servers whenever an overload occurs or is predicted to occur
- 4 Peak Shaving Control

Framework It spreads the data center's power demands more evenly over the entire billing cycle by making smart workload shifting and energy storage decisions which leads into great monetary reductions in the grid's peak demand penalties The framework accounts for real energy storage losses and constraints and considers a heterogeneous cloud workload that is made up of multiple classes with each class having different delay tolerance and price Several experiments based on real traces from a Google cluster show that our proposed frameworks achieve significant utilization gains energy reductions and monetary savings when compared to state of the art cloud resource management techniques

**Energy Efficient Data Centers** Jyrki Huusko, Hermann de Meer, Sonja Klingert, Andrey Somov, 2012-09-26 This book constitutes the thoroughly refereed post conference proceedings of the First International Workshop on Energy Efficient Data Centers E2DC 2012 held in Madrid Spain in May 2012 The 13 revised full papers presented were carefully selected from 32 submissions The papers cover topics from information and communication technologies of green data centers to business models and GreenSLA solutions The first section presents contributions in form of position and short papers related to various European projects The other two sections comprise papers with more in depth technical details The topics covered include energy efficient data center management and service delivery as well as energy monitoring and optimization techniques for data centers

Government Reports Annual Index, 1974      **Government Reports Index**, 1975      **Toward Energy-efficient Scheduling Using Weighted Round-robin and VM Reuse** Abdulaziz M. AlNowiser, 2013 In recent years the rapid evolving Cloud Computing technologies multiply challenges such as minimizing power consumption and meeting Quality of Services QoS requirements in the presence of heavy workloads from a large number of users using shared computing resources Powering a middle sized data center normally consumes 80 000kW power every year and computer servers consume around 5% of the global power 1 Statistics for 5000 production servers over a six month period show that only 10 50% of the total capacity has been effectively used and a large portion of the resources is actually wasted In order to address the skyrocket energy cost from the high level resource management aspect we propose an energy efficient job scheduling approach based on a modified version of Weighted Round Robin scheduler that incorporates VMs reuse and live VM migration without compromising the Service Level Agreement SLA The Weighted Round Robin scheduler can monitor the running VMs status for possible VM sharing for job consolidation or migration In addition the VMs utilization rate is observed to start live migration from the over utilizing Processing Element PE to under utilized PEs or to the hibernated PEs by sending WOL Wake On LAN signal to activate them The simulation experiments are conducted under the CloudReports environment based on open source CloudSim simulator The comparisons with other similar scheduling algorithms demonstrate that our enhanced Weighted Round Robin algorithm EWRR can achieve considerable better performance in terms of energy consumption and resource utilization rate

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that allow searching by authors of individual papers as well as by editors Includes proceedings in all formats i e books reports journal issues etc Complete bibliographical information for each conference proceedings appears in section titled Contents of proceedings with accompanying category permuterm subject sponsor author editor meeting location and corporate indexes Contains abbreviations used in organizational and geographical names Energy-Efficient Distributed Computing Systems Albert Y. Zomaya,Young Choon Lee,2012-07-26 The energy consumption issue in distributed computing systems raises various monetary environmental and system performance concerns Electricity consumption in the US doubled from 2000 to 2005 From a financial and environmental standpoint reducing the consumption of electricity is important yet these reforms must not lead to performance degradation of the computing systems These contradicting constraints create a suite of complex problems that need to be resolved in order to lead to greener distributed computing systems This book brings together a group of outstanding researchers that investigate the different facets of green and energy efficient distributed computing Key features One of the first books of its kind Features latest research findings on emerging topics by well known scientists Valuable research for grad students postdocs and researchers Research will greatly feed into other technologies and application domains Energy-efficient Resource Management for High-performance Computing Platforms ,2008 **Energy-Efficient Data Centers** Sonja Klingert,Xavier Hesselbach-Serra,Maria Perez Ortega,Giovanni Giuliani,2014-05-21 This book constitutes the thoroughly refereed post conference proceedings of the Second International Workshop on Energy Efficient Data Centers E2DC 2013 held in Berkeley CA USA in May 2013 co located with SIGCOMM e Energy 2013 The 8 revised full papers presented were carefully reviewed and selected from numerous submissions The papers are organized in topical sections on energy and workload measurement energy management simulators and control

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