

# Autonomic Management of Cloud Resources to meet Service Level Agreement

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**Abstract**—Several studies have used either Autonomic Resource Management (ARM) or Service Level Agreements (SLA) to manage cloud resources. To the best of our knowledge, no study has been conducted on SLA with ARM to maintain Quality-of-Services (QoS) features. Therefore, this study highlights the applications of ARM, which focused on providing cloud services automatically for cloud consumers. Prior research has shown that QoS-aware methods for enhancing cloud performance. Additionally, QoS maintains security at the same time, which depends on ARM and SLA. Thus, this study contributes to investigating dynamic autonomic Service-based applications (SBAs) in the cloud, which has not been addressed in previous studies. As a result, QoS in cloud security management did not cover self-protection. Consequently, this research suggests using ARM with SLA to maintain QoS techniques for providing self-protection requirements in a cloud environment.

**Keywords**—SLA, Cloud computing, Autonomic, management

## I. INTRODUCTION

Cloud computing is an infrastructure for an accessible shared pool of configurable computing resources over the internet. These resources are servers, storage, services, and applications that can be provisioned and released rapidly with minimal management effort and service provider involvement in the cloud environment[1]. However, the cloud provider should offer an infrastructure that makes the cloud resources adapt to any environmental changes and automatically preserve the quality of the services (QoS)[2]. This infrastructure, called autonomic infrastructure or self-management infrastructure, aims to automatically manage the cloud resources and respond to any business requirements based on Service Level Agreements (SLA)[3]. Thus, the self-management of the resources will enhance resource utilization performance and minimize their cost while ensuring the reliability and availability of the service[4]. The emergence of using autonomic management will require the autonomic manager or autonomic MAPE (Monitor, Analyzer, Planner, and Executor) loop[3]. This loop collects monitoring data from cloud resources to analyze them while generating planned changes to be executed on managed cloud services to correct violations (self-healing and self-protecting) or to aim for a new state of the system (self-configuring and self-optimizing)[2] [3]. However, managing the resources automatically will not fulfill the QoS alone without maintaining the SLA. The Service Level Agreement (SLA) refers to a legal contract

between the provider of the service and the consumer who is using this provided service[5]. Therefore, SLA can be utilized for measuring and reporting the performance of the cloud-consumed resources by the users [5]. Although some studies [4] [18] have the attention of either reaching autonomic management, other studies [3] [8] ignore the SLA that helps to fulfill QoS requirements. Thus, in this paper, we present the contribution of using the autonomic management approach with considering the SLA simultaneously for achieving QoS requirements that help resource provision with high quality. Besides, one of the QoS-aware autonomic techniques is considered in this study and has limited investigations in the previous studies called Self-protection. The rest of this paper is structured as follows. Section II is a background of the autonomic cloud resources and meeting the SLA concepts. In Section III, we review the related literature. In section IV, industry tools are provided to support this domain. Finally, our conclusion and future work are presented in Section V.

## II. BACKGROUND

### A. Autonomic Management of Cloud Resources

Autonomic cloud computing can be one of the options for optimal resource allocation by meeting user QoS needs automatically and healing unanticipated errors at runtime without human intervention [6]. Additionally, autonomy refers to a service's ability to control itself in response to its surroundings[7]. The autonomic system maintains system stability in unpredictable situations and adapts swiftly to new environmental conditions such as software and hardware failures. As a result, an SLA-aware autonomic resource management technique is required, which considers all critical QoS criteria such as availability, cost, latency, and execution time, among others [7]. Indeed, autonomic computing systems can be widely employed for dynamic resource management in the face of changing workloads, reducing the need for human intervention in resource management. It can react to changes and recommend appropriate steps before SLA violations occur [8].

To obtain autonomic computing, IBM proposed the autonomic manager as a reference model for the autonomic controller. IBM proposed the autonomic manager as a reference model for the autonomic controller, composed of four fundamental components that monitor cloud resources, evaluate monitoring data, plan, and execute configuration

# Autonomic Management Of Virtualized Resources In Cloud

**CH Cherryholmes**



## **Autonomic Management Of Virtualized Resources In Cloud:**

Advances in Service-Oriented and Cloud Computing Antonio Celesti, Philipp Leitner, 2016-04-26 This volume contains the technical papers presented in the seven high quality workshops associated with the European Conference on Service Oriented and Cloud Computing ESOC 2015 held in Taormina Italy in September 2015 Third International Workshop on Cloud for IoT CLIoT 2015 5th International Workshop on Adaptive Services for the Future Internet WAS4FI 2015 Second Workshop on Seamless Adaptive Multi cloud Management of Service Based Applications SeaClouds 2015 First International Workshop on Cloud Adoption and Migration CloudWay 2015 First International Workshop on Digital Enterprise Architecture and Engineering IDEA 2015 First Workshop on Federated Cloud Networking FedCloudNet 2015 Abstracts of the presentations held at the European Projects Forum EU Projects 2015 are included in the back matter of this volume The 25 full papers and 6 short papers were carefully reviewed and selected from 48 submissions They focus on specific topics in service oriented and cloud computing domains such as limits and or advantages of existing cloud solutions Future Internet technologies efficient and adaptive deployment and management of service based applications across multiple clouds novel cloud service migration practices and solutions digitization of enterprises in the cloud computing era federated cloud networking services

### **Building a National Distributed E-Infrastructure -- PL-Grid**

Marian Bubak, Tomasz Szepieniec, Kazimierz Wiatr, 2012-03-02 This book describes scientific results obtained by project partners and outcomes of research and development activities carried out within the Polish Infrastructure for Information Science Support in the European Research Space PL Grid PL Grid 2011

*Cloud Computing for Data-Intensive Applications* Xiaolin Li, Judy Qiu, 2014-12-02 This book presents a range of cloud computing platforms for data intensive scientific applications It covers systems that deliver infrastructure as a service including HPC as a service virtual networks as a service scalable and reliable storage algorithms that manage vast cloud resources and applications runtime and programming models that enable pragmatic programming and implementation toolkits for eScience applications Many scientific applications in clouds are also introduced such as bioinformatics biology weather forecasting and social networks Most chapters include case studies Cloud Computing for Data Intensive Applications targets advanced level students and researchers studying computer science and electrical engineering Professionals working in cloud computing networks databases and more will also find this book useful as a reference

On the Move to Meaningful Internet Systems: OTM 2015 Conferences Christophe Debruyne, Hervé Panetto, Robert Meersman, Tharam Dillon, Georg Weichhart, Yuan An, Claudio Agostino Ardagna, 2015-10-29 This volume constitutes the refereed proceedings of the Confederated International Conferences Cooperative Information Systems CoopIS 2015 Ontologies Databases and Applications of Semantics ODBASE 2015 and Cloud and Trusted Computing C TC held as part of OTM 2015 in October 2015 in Rhodes Greece The 30 full papers presented together with 15 short papers were carefully reviewed and selected from 144 initial submissions The OTM program every year covers data and Web

semantics distributed objects Web services databases information systems enterprise workflow and collaboration ubiquity interoperability mobility grid and high performance computing

**On the Move to Meaningful Internet Systems: OTM 2016 Conferences** Christophe Debruyne, Hervé Panetto, Robert Meersman, Tharam Dillon, Eva Kühn, Declan O'Sullivan, Claudio Agostino Ardagna, 2016-10-17 This volume constitutes the refereed proceedings of the Confederated International Conferences Cooperative Information Systems CoopIS 2016 Ontologies Databases and Applications of Semantics ODBASE 2016 and Cloud and Trusted Computing C TC held as part of OTM 2016 in October 2016 in Rhodes Greece The 45 full papers presented together with 16 short papers were carefully reviewed and selected from 133 submissions The OTM program every year covers data and Web semantics distributed objects Web services databases information systems enterprise workow and collaboration ubiquity interoperability mobility grid and high performance computing

**Euro-Par 2011: Parallel Processing Workshops** Michael Alexander, Pasqua D'Ambra, Adam Belloum, George Bosilca, Mario Cannataro, Marco Danelutto, Beniamino Di Martino, Michael Gerndt, Emmanuel Jeannot, Raymond Namyst, Jean Roman, Stephen L. Scott, Jesper Larsson Traff, Geoffroy Vallee, Josef Weidendorfer, 2012-04-14 This book constitutes thoroughly refereed post conference proceedings of the workshops of the 17th International Conference on Parallel Computing Euro Par 2011 held in Bordeaux France in August 2011 The papers of these 12 workshops CCPI CGWS HeteroPar HiBB HPCVirt HPPC HPSS HPCF PROPER CCPI and VHPC focus on promotion and advancement of all aspects of parallel and distributed computing

*Green Communications* Jinsong Wu, Sundeep Rangan, Honggang Zhang, 2016-04-19 Nowadays energy crisis and global warming problems are hanging over everyone's head urging much research work on energy saving In the ICT industry which is becoming a major consumer of global energy triggered by the telecommunication network operators experiencing energy cost as a significant factor in profit calculations researchers have start

*The Future Internet* John Domingue, Alex Galis, Anastasius Gavras, Theodore Zahariadis, Dave Lambert, Frances Cleary, Petros Daras, Srdjan Krco, Henning Müller, Man-Sze Li, Hans Schaffers, Volkmar Lotz, Federico Alvarez, Burkhard Stiller, Stamatis Karnouskos, Susanna Avessta, Michael Nilsson, 2011-04-08 Irrespective of whether we use economic or societal metrics the Internet is one of the most important technical infrastructures in existence today It will be a catalyst for much of our innovation and prosperity in the future A competitive Europe will require Internet connectivity and services beyond the capabilities offered by current technologies Future Internet research is therefore a must This book is published in full compliance with the Open Access publishing initiative it is based on the research carried out within the Future Internet Assembly FIA It contains a sample of representative results from the recent FIA meetings spanning a broad range of topics all being of crucial importance for the future Internet The book includes 32 contributions and has been structured into the following sections each of which is preceded by a short introduction Foundations architectural issues socio economic issues security and trust and experiments and experimental design Future Internet Areas networks services and content and

applications     **Standard Handbook for Electrical Engineers, Seventeenth Edition** Surya Santoso,H. Wayne Beaty,2017-11-24 Up to date coverage of every facet of electric power in a single volume This fully revised industry standard resource offers practical details on every aspect of electric power engineering The book contains in depth discussions from more than 100 internationally recognized experts Generation transmission distribution operation system protection and switchgear are thoroughly explained Standard Handbook for Electrical Engineers Seventeenth Edition features brand new sections on measurement and instrumentation interconnected power grids smart grids and microgrids wind power solar and photovoltaic power generation electric machines and transformers power system analysis operations stability and protection and the electricity market Coverage includes Units symbols constants definitions and conversion factors Measurement and instrumentation Properties of materials Interconnected power grids AC and DC power transmission Power distribution Smart grids and microgrids Wind power generation Solar power generation and energy storage Substations and switch gear Power transformers generators motors and drives Power electronics Power system analysis operations stability and protection Electricity markets Power quality and reliability Lightning and overvoltage protection Computer applications in the electric power industry Standards in electrotechnology telecommunications and IT     Cloud Computing Thomas Erl,Ricardo Puttini,Zaigham Mahmood,2013-05-02 Clouds are distributed technology platforms that leverage sophisticated technology innovations to provide highly scalable and resilient environments that can be remotely utilized by organizations in a multitude of powerful ways To successfully build upon integrate with or even create a cloud environment requires an understanding of its common inner mechanics architectural layers and models as well as an understanding of the business and economic factors that result from the adoption and real world use of cloud based services In **Cloud Computing Concepts Technology Architecture** Thomas Erl one of the world s top selling IT authors teams up with cloud computing experts and researchers to break down proven and mature cloud computing technologies and practices into a series of well defined concepts models technology mechanisms and technology architectures all from an industry centric and vendor neutral point of view In doing so the book establishes concrete academic coverage with a focus on structure clarity and well defined building blocks for mainstream cloud computing platforms and solutions Subsequent to technology centric coverage the book proceeds to establish business centric models and metrics that allow for the financial assessment of cloud based IT resources and their comparison to those hosted on traditional IT enterprise premises Also provided are templates and formulas for calculating SLA related quality of service values and numerous explorations of the SaaS PaaS and IaaS delivery models With more than 260 figures 29 architectural models and 20 mechanisms this indispensable guide provides a comprehensive education of cloud computing essentials that will never leave your side     **21st Acm Symposium on Operating Systems Principles (Sosp '07)**. ,2009     An Autonomic Framework Supporting Task Consolidation and Migration in the Cloud Environment Jiedan Zhu,2011 Abstract Cloud Computing systems provide a variety of storage and computation resources

One advantage is the pay as you go model where users only pay the fee for the amount of resource they have used. There could be some user specific concerns such as a time constraint and a cost budget. However, without resource scheduling and management in the Cloud environment, virtual instances could be under utilized and users may pay more than expected, which might not satisfy the user requirements. Cloud service providers hide the control of physical resources from users. In this thesis, we designed an autonomic framework which supports task consolidation and light weighted migration over the virtual resources in the Cloud environment. We focus on DAG based workflows and the user constraints are time constraint and cost budget. Our goal is to keep the application to complete within the time constraint while the cost is within the cost budget. We have developed three techniques with different kinds of prior knowledge: the CPU and memory requirements of tasks, iteration structures of workflows, and iteration structures of tasks. We show that our system is effective and can save the cost up to 66% compared with the case when there is no resource scheduling. In addition, we compared system performance with three techniques and we found that with the CPU and memory requirements of tasks as the prior knowledge, our system has a better performance price ratio than the other two prior knowledge.

Autonomic Computing in Cloud Resource Management in Industry 4.0 Tanupriya Choudhury, Bhupesh Kumar Dewangan, Ravi Tomar, Bhupesh Kumar Singh, Teoh Teik Toe, Nguyen Gia Nhu, 2021-08-04. This book describes the next generation of industry Industry 4.0 and how it holds the promise of increased flexibility in manufacturing along with automation, better quality, and improved productivity. The authors discuss how it thus enables companies to cope with the challenges of producing increasingly individualized products with a short lead time to market and higher quality. The authors posit that intelligent cloud services and resource sharing play an important role in Industry 4.0, anticipated Fourth Industrial Revolution. This book serves the different issues and challenges in cloud resource management. CRM techniques with proper propped solution for IT organizations. The book features chapters based on the characteristics of autonomic computing with its applicability in CRM. Each chapter features the techniques and analysis of each mechanism to make better resource management in cloud.

Collaborative Policy-based Autonomic Management in IaaS Clouds Omid Mola, 2013. With the increasing number of machines, either virtual or physical, in a computing environment, it is becoming harder to monitor and manage these resources. Relying on human administrators, even with tools, is expensive and the growing complexity makes management even harder. The alternative is to look for automated approaches that can monitor and manage computing resources in real time with no human intervention. One of the approaches to this problem is policy based autonomic management. However, in large systems, having one single autonomic manager to manage everything is almost impossible. Therefore, multiple autonomic managers will be needed and these will need to cooperate in the overall management. We propose a management model using multiple autonomic managers organized in a hierarchical fashion to monitor and manage the resources in a computing environment based on provided policies. We develop a communication protocol to facilitate collaboration between different autonomic managers, define the

core operations of these managers and introduce algorithms to deal with their deployment and operation We also introduce an approach for the inference of the communication messages from policies and develop several algorithms for joining and maintaining the management hierarchy We propose a deployment system that can discover relevant resources in a computing environment automatically to facilitate the deployment of autonomic managers at different levels of a physical system We then test our approach by implementing it in a small private Infrastructure as a Service IaaS cloud and show how this collaboration of autonomic managers in a hierarchical way can help to adopt to high stress situations automatically and reduce the SLA violation rate without adding any new resource to the environment

Optimization of Autonomic Resources for the Management of Service-based Business Processes in the Cloud Leila Hadded,2018 Cloud Computing is a new paradigm that provides computing resources as a service over the internet in a pay per use model It is increasingly used for hosting and executing business processes in general and service based business processes SBPs in particular Cloud environments are usually highly dynamic Hence executing these SBPs requires autonomic management to cope with the changes of cloud environments implies the usage of a number of controlling devices referred to as Autonomic Managers AMs However existing solutions are limited to use either a centralized AM or an AM per service for managing a whole SBP It is obvious that the latter solution is resource consuming and may lead to conflicting management decisions while the former one may lead to management bottlenecks An important problem in this context deals with finding the optimal number of AMs for the management of an SBP minimizing costs in terms of number of AMs while at the same time avoiding management bottlenecks and ensuring good management performance Moreover due to the heterogeneity of cloud resources and the diversity of the required quality of service QoS of SBPs the allocation of cloud resources to these AMs may result in high computing costs and an increase in the communication overheads and or lower QoS It is also crucial to find an optimal allocation of cloud resources to the AMs minimizing costs while at the same time maintaining the QoS requirements To address these challenges in this work we propose a deterministic optimization model for each problem Furthermore due to the amount of time needed to solve these problems that grows exponentially with the size of the problem we propose near optimal algorithms that provide good solutions in reasonable time

*International Aerospace Abstracts* ,1997 **Science Citation Index** ,1992 Vols for 1964 have guides and journal lists Autonomic Management of Service Level Agreements in Cloud Computing Stefan Edwin Karl Frey,2021 **Fog and Edge Computing** Rajkumar Buyya,Satish Narayana Srirama,2019-01-04 A comprehensive guide to Fog and Edge applications architectures and technologies Recent years have seen the explosive growth of the Internet of Things IoT the internet connected network of devices that includes everything from personal electronics and home appliances to automobiles and industrial machinery Responding to the ever increasing bandwidth demands of the IoT Fog and Edge computing concepts have developed to collect analyze and process data more efficiently than traditional cloud architecture Fog and Edge Computing Principles and Paradigms provides a comprehensive

overview of the state of the art applications and architectures driving this dynamic field of computing while highlighting potential research directions and emerging technologies Exploring topics such as developing scalable architectures moving from closed systems to open systems and ethical issues rising from data sensing this timely book addresses both the challenges and opportunities that Fog and Edge computing presents Contributions from leading IoT experts discuss federating Edge resources middleware design issues data management and predictive analysis smart transportation and surveillance applications and more A coordinated and integrated presentation of topics helps readers gain thorough knowledge of the foundations applications and issues that are central to Fog and Edge computing This valuable resource Provides insights on transitioning from current Cloud centric and 4G 5G wireless environments to Fog Computing Examines methods to optimize virtualized pooled and shared resources Identifies potential technical challenges and offers suggestions for possible solutions Discusses major components of Fog and Edge computing architectures such as middleware interaction protocols and autonomic management Includes access to a website portal for advanced online resources Fog and Edge Computing Principles and Paradigms is an essential source of up to date information for systems architects developers researchers and advanced undergraduate and graduate students in fields of computer science and engineering Towards Autonomic Virtual Machine Management Siddharth Wagh,2010 Virtual machine technologies are gaining wide acceptance in today s era due to invaluable services in system management server consolidation and secure resource containment along with providing requisite application execution environment Every virtual machine platform reduces dependence on hardware by fully or partially abstracting operating systems enabling flexible control of manipulation or migration of guest machines by manual system administration or reactive proactive approaches to management This dissertation focuses on resolving the resource reservation problem to help define a mathematical model and study interference within multiple virtual machines while trying to achieve load balancing and improve performance efficiency Our goal is three pronged Firstly we aim to understand the underlying support available for virtual machine migration and pursue new technologies or abstractions to improve efficiency and speed of the data transfer Secondly we carefully evaluate all the resources used by VMs for proper functioning and study the synchronization and multiplexing processes underneath which delineate when and where to migrate a virtual machine Finally we attempt to deduce the action to perform on running VMs manipulation or resource configuration so as to resolve the issue at hand To achieve these goals we follow a step by step procedure limiting the number of variable parameters and analyze the outcome of focal experiments The results show that using RDMA Remote Direct Memory Access to perform virtual machine migration can be used only in scenarios where the underlying hardware offers support for such transactions eg InfiniBand architecture and such an abstraction over TCP IP does not ameliorate efficiency of VM transfers Further a utility based function designed to analyze environment and application metrics and project an area of good bad states on a map would require a plethora of parameters increasing its complexity Considering

VM re distribution one can predict the ideal number and time of migration of guest virtual machines on any configuration by gathering statistics from parallel migration for graphical analysis Parallel VM migration gives us shorter average transfer time and higher latencies per VM Pinning of virtual CPUs to VMs improves the performance efficiency of applications compared to sharing of CPUs

Autonomic Management Of Virtualized Resources In Cloud: Bestsellers in 2023 The year 2023 has witnessed a noteworthy surge in literary brilliance, with numerous engrossing novels enthraling the hearts of readers worldwide. Lets delve into the realm of popular books, exploring the engaging narratives that have captivated audiences this year. Autonomic Management Of Virtualized Resources In Cloud : Colleen Hoover's "It Ends with Us" This heartfelt tale of love, loss, and resilience has gripped readers with its raw and emotional exploration of domestic abuse. Hoover expertly weaves a story of hope and healing, reminding us that even in the darkest of times, the human spirit can prevail. Autonomic Management Of Virtualized Resources In Cloud : Taylor Jenkins Reids "The Seven Husbands of Evelyn Hugo" This captivating historical fiction novel unravels the life of Evelyn Hugo, a Hollywood icon who defies expectations and societal norms to pursue her dreams. Reids absorbing storytelling and compelling characters transport readers to a bygone era, immersing them in a world of glamour, ambition, and self-discovery. Discover the Magic : Delia Owens "Where the Crawdads Sing" This mesmerizing coming-of-age story follows Kya Clark, a young woman who grows up alone in the marshes of North Carolina. Owens crafts a tale of resilience, survival, and the transformative power of nature, entrancing readers with its evocative prose and mesmerizing setting. These popular novels represent just a fraction of the literary treasures that have emerged in 2023. Whether you seek tales of romance, adventure, or personal growth, the world of literature offers an abundance of compelling stories waiting to be discovered. The novel begins with Richard Papen, a bright but troubled young man, arriving at Hampden College. Richard is immediately drawn to the group of students who call themselves the Classics Club. The club is led by Henry Winter, a brilliant and charismatic young man. Henry is obsessed with Greek mythology and philosophy, and he quickly draws Richard into his world. The other members of the Classics Club are equally as fascinating. Bunny Corcoran is a wealthy and spoiled young man who is always looking for a good time. Charles Tavis is a quiet and reserved young man who is deeply in love with Henry. Camilla Macaulay is a beautiful and intelligent young woman who is drawn to the power and danger of the Classics Club. The students are all deeply in love with Morrow, and they are willing to do anything to please him. Morrow is a complex and mysterious figure, and he seems to be manipulating the students for his own purposes. As the students become more involved with Morrow, they begin to commit increasingly dangerous acts. The Secret History is a masterful and gripping novel that will keep you wondering until the very end. The novel is a warning tale about the dangers of obsession and the power of evil.

<https://matrix.jamesarcher.co/About/uploaded-files/HomePages/STEM%20For%20Kids%20Hardcover.pdf>

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