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Automated Workflow Scheduling in Self-Adaptive Clouds

Concepts, Algorithms and Methods

Springer

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Foreword

Enterprise-class software applications are steadily embracing the cloud idea in order to succulently reap all the originally envisaged cloud benefits. Due to the on-demand utility and elastic nature of virtualized and containerized infrastructures that are the real hallmark of any cloud environments (private, public, and hybrid), scores of mission-critical workloads are being accordingly modernized (cloud-enabled) and migrated to cloud environments to be delivered with all alacrity and authentication to worldwide clients and consumers. On the other hand, of late, there are cloud-native applications gaining prominence. There are business, technical, embedded, social, operational, transactional, and analytical applications efficiently running on cloud hosts. The cloud paradigm is definitely on the fast track. That is, we are all set to experience software-defined cloud environments in the days ahead. Precisely speaking, clouds emerge as the one-stop IT solution for hosting, delivering, billing, monitoring, measuring, managing, and maintaining all kinds of simple as well as complex workloads.

As I see, this book is all about expressing and exposing the various automated workflow scheduling algorithms and approaches for various process-centric cloud-based applications. Workflow is typically described by a Directed Acyclic Graph (DAG) in which each computational task is represented by nodes and each data/control dependency between tasks is annotated through edges that intrinsically connect nodes. Workflow scheduling is therefore recognized as one of the most vital requirements for hosting workflow-centric applications in cloud environments. There are quality of service (QoS) constraints such as the timeliness, throughput, minimal cost, minimal makespan and maximal resource utilization, etc. The other widely articulated and accentuated challenge is the efficient resource utilization and optimizing the total execution time (makespan) of the workflow.

Having understood the intricacies of workflow applications and the state-of-the-art workflow/task/job scheduling algorithms, the authors of this comprehensive yet compact book have clearly detailed the enterprise-grade software applications and their scheduling needs in cloud environments. This book covers most of the topics that are needed for cloud consultants, architects, and administrators. The cloud service providers (CSPs) across the globe are leveraging a variety of scheduling

algorithms in order to enhance resource utilization of highly virtualized IT environments for bringing down the cloud operational costs. I am sure that this book is a must for professionals who are manning next-generation software-defined cloud environments. Finally, research students, scholars, and scientists are bound to be benefited immensely through this book.

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Preface

Two things are clearly noteworthy here. There is a heightened heterogeneity of cloud IT resources, whose distributed nature also is on the climb. Further on, the multiplicity of software applications leveraging various cloud resources is steadily growing. All these points to the fact that the IT development, deployment, delivery, and management complexities are bound to escalate sharply in the days ahead. There are pioneering technologies, enabling tools, and advanced algorithms emerging and evolving fast, and if they are applied correctly, the threatening complexity of new-generation IT environments is bound to decline substantially. Academic professors and IT industry professionals across the globe hence work collaboratively to unearth a bevy of workable solutions for the abovementioned IT challenges. Optimized and organized scheduling of jobs/tasks/workflows of process-aware, service-oriented, event-driven, cloud-centric, and enterprise-scale applications is one forward-looking complexity-mitigation requirement for the impending cloud IT era. This book is expertly crafted to describe the various workflow scheduling algorithms and approaches, which are becoming indispensable to bring a kind of sanity and also to run all kinds of software applications (cloud-enabled and cloud-native) by efficiently leveraging different and distributed cloud resources.

Chapter 1 (Stepping into the Digital Intelligence Era) is to talk about the digitization technologies and how myriads of digitized entities and elements are being systematically realized and deployed in our daily environments. Further on, the chapter digs deeper and describes how the connected era emerges and evolves, how the massive amount of data getting generated are subjected to a variety of investigations to squeeze out viable and venerable insights, and finally how the knowledge extracted is delivered to facilitate correct decision-making and action in time. The chapter ends with how digitization and the paradigm of cognitive computing converge with one another in order to make the path smooth for the forthcoming era of digital intelligence.

Chapter 2 (Demystifying the Traits of Software-Defined Cloud Environments (SDCEs)) is specially crafted to tell all about the cloud journey. We have started with the brief of age-old server virtualization and then proceeded to explain how other cloud resources especially storage and network are getting virtualized. The

brewing trend is to have completely virtualized IT environments by appropriately leveraging cloud technologies. There are virtual machine monitors (VMMs), integration tools, orchestration engines for automated provisioning and software deployment, service brokers for multi-cloud solutions, integrated monitoring, measurement and management systems, job schedulers, capacity planning and configuration tools, a plenty of security algorithms and approaches, and other automated solutions to have next-generation cloud environments. The readers can find the details in the second chapter.

Chapter 3 (Workflow Management Systems) is incorporated to give a detailed explanation of workflow management systems. Today's scientific applications require a tremendous amount of computation-driven as well as data-driven supported resources. Typically scientific applications are represented as workflows. The workflow management systems are designed and developed to depict the workflows of complex nature. The workflow management systems are able to reliably and efficiently coordinate among various resources in a distributed environment. This chapter describes various workflow management software solutions such as Kepler, Taverna, Triana, Pegasus, and Askalon. The architecture and functionalities of these workflow management systems are explained in a lucid manner.

Chapter 4 (Workflow Scheduling Algorithms and Approaches) is to explain the nitty-gritty of various workflow scheduling algorithms. Cloud infrastructures typically offer access to boundless virtual resources dynamically provisioned on demand for hosting, running, and managing a variety of mission-critical applications. Efficient scheduling algorithms become mandatory for automated operations of distributed and disparate cloud resources and workloads. The resource scheduling is a dynamic problem; it is associated with on-demand resource provisioning, fault tolerance support, hybrid resource scheduling with appropriate quality of service, and considering time, cost, and budget. This chapter provides the details about various automated solutions for workflow scheduling and also a comprehensive survey of various existing workflow scheduling algorithms in the cloud computing environment.

Chapter 5 (Workflow Modeling and Simulation Techniques) is to detail the prominent and dominant workflow modeling and simulation techniques and tips. Modeling and simulation of scientific workflow play a vital role in resource allocation in a distributed environment. Simulation is one of the methods to solve the complex scientific workflows in distributed environment. There are many scientific workflow simulation software frameworks that are available for grid and cloud environment. WorkflowSim is an open-source simulator. WorkflowSim Simulator extends the existing CloudSim Simulator. The architecture, components, and scheduling algorithms used and also the simulation results are explained for the CloudSim Simulator and WorkflowSim Simulator.

Chapter 6 (Execution of Workflow Scheduling in Cloud Middleware) is to converge the workflow capabilities in cloud environments. Many scientific applications are often modeled as workflows. The data and computational resource requirements are high for such workflow applications. Cloud provides a better solution to this problem by offering a promising environment for the execution of these workflows.

As it involves tremendous data computations and resources, there is a need to automate the entire process. The workflow management system serves this purpose by orchestrating workflow task and executes it on distributed resources. Pegasus is a well-known workflow management system that has been widely used in large-scale e-applications. This chapter provides an overview of the Pegasus Workflow Management System and describes the environmental setup with OpenStack, creation, and execution of workflows in Pegasus and discusses the workflow scheduling in the cloud with its issues.

Chapter 7 (Workflow Predictions Through Operational Analytics and Machine Learning) is an important one for this book. Data analytics is the widely recognized mechanism to squeeze out important information out of historical as well as current data heaps. The advancements in the fields of operational analytics and machine learning (ML) clearly could foretell everything to accurately predict workflows. Increasingly workflow execution employs predictive analytics to extract significant, unidentified, as well as precious insights from several stages of execution. Further, the operational analytics integrates these valuable insights directly into the decision engine which enables analytical as well as machine learning-driven decision-making for an efficient workflow execution. This chapter highlights several analytical and machine learning approaches that are practiced in workflow predictions. Additionally, it explains the significance of a hybrid approach which includes both analytical and machine learning models for workflow prediction. Finally, it describes the hybrid approach employed in PANORAMA architecture using two workflow applications.

Chapter 8 (Workflow Integration and Orchestration, Opportunities and Challenges) is prepared and presented in order to explain how workflow orchestration is being performed. Workflow orchestration is a method which smartly organizes the enterprise function with the application, data, and infrastructure. The applications, as well as their infrastructure, can be dynamically scaled up or down using orchestration. On the contrary, the integration enables the development of new applications with the capability to connect to any other application through specified interfaces. In this chapter, firstly, the opportunities and challenges in workflow orchestration and integration are explained. Following that, BioCloud, an architecture that demonstrates the task-based workflow orchestration using two bioinformatics workflows, is explained in detail.

Chapter 9 (Workload Consolidation Through Automated Workload Scheduling) illustrates how workload consolidation and optimization lead to heightened resource utilization. Workload consolidation is an approach to enhance the server utilization by grouping the VMs that are executing workflow tasks over multiple servers based on their server utilization. The primary objective is to optimally allocate the number of servers for executing the workflows which in turn minimize the cost and energy of data centers. This chapter consolidates the cost- and energy-aware workload consolidation approaches along with the tools and methodologies used in modern cloud data centers.

Chapter 10 (Automated Optimization Methods for Workflow Execution) deals with how various optimization methods guarantee optimal execution of workflows.

Workflow optimization is an approach to enhance the speed, robustness, and compactness of workflows by exploiting their structure, runtime, and output. This chapter initially highlights the significance of workflow optimization along with different possible levels of optimization. Further, it outlines the Taverna optimization framework over single and distributed infrastructure together with the optimization plugins that is validated using two scientific workflow executions.

Chapter 11 (The Hybrid IT: The Characteristics and Capabilities) is to give an idea of the emerging hybrid IT domain. With the faster adoption of the cloud idea across industry verticals with all the elegance and the enthusiasm, the traditional IT is bound to enlarge its prospects and potentials. This is a kind of new IT getting enormous attention and garnering a lot of attraction among business executives and IT professionals lately. The systematic amalgamation of the cloud concepts with the time-tested and trusted enterprise IT environment is to deliver a bevy of significant advantages for business houses in the days ahead. This model of next-generation computing through the cognitive and collective leverage of enterprise and cloud IT environments is being touted as the hybrid IT. This chapter is specially crafted for digging deep and describing the various implications of the hybrid IT.

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