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Review

Towards workflow scheduling in cloud computing: A comprehensive analysis

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ABSTRACT

Workflow scheduling is one of the prominent issues in cloud computing which is aimed at complete execution of workflows by considering their QoS requirements such as deadline and budget constraints. Numerous state of the art workflow scheduling schemes have been proposed in the literature for scheduling simple and scientific workflows in the cloud computing and this paper presents a comprehensive survey and analysis of these schemes. It illuminates the objectives of scheduling schemes in the cloud computing and provides a classification of the proposed schemes based on the type of scheduling algorithm applied in each scheme. Beside, each scheme is illustrated and a complete comparison of them is presented to highlight their objectives, properties and limitations. Finally, the concluding remarks and future research directions are provided.

Contents

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1. Introduction

Cloud computing is a technology that utilizes the internet and central remote servers to provide scalable services for its users (Kaur et al., 2011). It uses a great amount of heterogeneous distributed resources to deliver countless different services to its users with distinctive quality of service (QoS) requirements (Wu et al., 2013). Amazon EC2, GoGrid, Google App Engine, Microsoft Azure and Aneka are some of the prominent cloud computing platforms.

Generally, clouds are classified as public clouds, private clouds, community clouds, hybrid clouds and cloud federation (Huang, 2014). A public cloud can be accessed by any subscriber (Huth and Cebula, 2011), but private clouds and their infrastructure are owned and accessed by some organizations (Huang, 2014). Also, community clouds are shared between several organizations and can be maintained by them or other service providers (Huang, 2014). Hybrid clouds deal with resources from both public and private clouds (Marcon et al., 2013). Also, due to the availability issue of the single clouds, a movement towards multi-clouds has emerged (AlZain et al., 2012) which focuses on the federation of different clouds (Jensen et al., 2011; Buyya et al., 2010).

In addition, the services provided by cloud can be classified as software (SaaS), platform (PaaS), or infrastructure (IaaS) providers (Wang et al., 2014). SaaS provider leases enterprise software as a service to customers (Wu et al., 2011) and PaaS provider presents access to the required components over the internet to develop applications (Basishtha and Boruah). Also, IaaS clouds provide infrastructures resources such as processing, storage, networks, and soon (Dillon et al., 2010; Agarwal and Jain, 2014).

Virtualization is one of the key enabling technologies of cloud computing which allows multiple Virtual Machines (VMs) to reside on a single physical machine (Pandey et al., 2010). A Virtual Machine (VM) emulates a particular computer system and executes the user issued tasks (Wang et al., 2010). By using the instantiation of the VMs, users can deploy their applications on resources with various performance and cost levels. In each physical machine or server, the VMs are managed by a software layer called hypervisor or the VM monitor which facilitates the VMs creation and isolated execution.

Workflow scheduling is one of the prominent issues in the cloud computing which tries to map the workflow tasks to the VMs based on different functional and non-functional requirements (Jayadivya and Bhanu, 2012). A workflow consists of a series of interdependent tasks which are bounded together through data or functional dependencies and these dependencies should be considered in the scheduling (Kumar, 2014). However, workflow scheduling in the cloud computing is an NP-hard optimization problem and it is difficult to achieve an optimal schedule. Because there are numerous VMs in a cloud and many user tasks should be scheduled by considering various scheduling objectives and factors. The common objective of the workflow scheduling techniques is to minimize the makespan by the proper allocation of the tasks to the virtual resources (Rahman et al., 2013; Bala and Chana, 2011). For example, a scheduling scheme may try to support the promised SLAs, the user specified deadlines and cost constraints (Kapoor and Kakkar). Also, scheduling solutions may consider factors such as resource utilization, load balancing and availability of the cloud resources and services in the scheduling decisions (Bala and Chana, 2011; Maruthanayagam and Prakasam; Motahari-Nezhad et al., 2009; Barrett et al., 2011).

The workflow scheduling problem has been widely studied in the literature. This paper presents a complete survey of the workflow scheduling schemes proposed for cloud computing in the literature. For this purpose, it first illuminates the types and objectives of workflow scheduling and then provides a classification of the proposed schemes based on the algorithm which has been used in each workflow scheduling scheme. Also, the objectives, properties and the limitations of workflow scheduling schemes are assessed in detail and a complete comparison of them is presented. Although some schemes such as (Kaur; Nallakumar, 2014; Singh and Singh, 2013) discussed the workflow scheduling problem in cloud environment, none of them have provided an in-depth investigation and comparison of the proposed workflow scheduling schemes.

The rest of this article is organized as follows: Section 2 discusses about the workflow scheduling types and objectives, Section 3 investigates the proposed workflow scheduling and compares various aspects of them. Section 4 discusses about the cloud providers and simulators, Section 5 presents the comparison and discussion of the proposed schemes, and Section 6 exhibits the concluding remarks and future research directions.

2. Types and objectives of scheduling in cloud

Generally, there are two types of workflow which are simple and scientific workflows. Figure 1 indicates a simple workflow's DAG which contains 9 tasks.