Journal of Network and Computer Applications 52 (2015) 11–25

Contents lists available at ScienceDirect

Journal of Network and Computer Applications

journal homepage: www.elsevier.com/locate/jnca

Review

# A survey on virtual machine migration and server consolidation frameworks for cloud data centers

Raja Wasim Ahmad [a,*], Abdullah Gani [a], Siti Hafizah Ab. Hamid [a], Muhammad Shiraz [a], Abdullah Yousafzai [a], Feng Xia [b]

[a] Center for Mobile Cloud Computing (C4MCC), FSKTM, University of Malaya, Malaysia
[b] School of Software, Dalian University of Technology, China

ARTICLE INFO

*Article history:*
Received 21 August 2014
Received in revised form
17 December 2014
Accepted 10 February 2015
Available online 5 March 2015

*Keywords:*
Virtualization
Server consolidation
VM migration
Data center
QoS

ABSTRACT

Modern Cloud Data Centers exploit virtualization for efficient resource management to reduce cloud computational cost and energy budget. Virtualization empowered by virtual machine (VM) migration meets the ever increasing demands of dynamic workload by relocating VMs within Cloud Data Centers. VM migration helps successfully achieve various resource management objectives such as load balancing, power management, fault tolerance, and system maintenance. However, being resource-intensive, the VM migration process rigorously affects application performance unless attended by smart optimization methods. Furthermore, a Cloud Data Centre exploits server consolidation and DVFS methods to optimize energy consumption. This paper reviews state-of-the-art bandwidth optimization schemes, server consolidation frameworks, DVFS-enabled power optimization, and storage optimization methods over WAN links. Through a meticulous literature review of state-of-the-art live VM migration schemes, thematic taxonomies are proposed to categorize the reported literature. The critical aspects of virtual machine migration schemes are investigated through a comprehensive analysis of the existing schemes. The commonalties and differences among existing VM migration schemes are highlighted through a set of parameters derived from the literature. Finally, open research issues and trends in the VM migration domain that necessitate further consideration to develop optimal VM migration schemes are highlighted.



**Contents**



* Corresponding author. Tel.: +60 107891697; fax: +60 379579249.
*E-mail addresses:* wasimraja@siswa.um.edu.my (R.W. Ahmad), abdullah@um.edu.my (A. Gani), sitihafizah@um.edu.my (S.H.Ab. Hamid), muh_shiraz@yahoo.com (M. Shiraz), abdullahyousafzai@siswa.um.edu.my (A. Yousafzai), f.xia@acm.org (F. Xia).

http://dx.doi.org/10.1016/j.jnca.2015.02.002
1084-8045/

## 1. Introduction

Inefficient resource management policies poorly exploit system resources within Cloud Data Centers (CDC). CDCs are normally over-provisioned to assure high service availability and application quality of service (QoS) (Beloglazov and Buyya, 2013). On an average, 30% of cloud servers exploit 10–15% of resource capacity most of the time (Uddin et al., 2013). Circumscribed resource utilization results in astonishingly high CDC operational cost and energy usage. Google Data Centers are estimated to have consumed 260 million Watts of energy (0.01% of the world's energy) in 2013 (Koomey, 2011; Server (2013)). Having adequate processing power, today's CDC servers host plenty of applications for efficient resource management to optimize energy consumption. To scale a CDC, virtualization exploits VM migration to relocate VMs both within and across CDCs to achieve various resource management objectives like server maintenance provisioning, power reduction, load balancing, and fault tolerance (Koomey, 2008; Voorsluys et al., 2009). Further, a CDC provides the foundation for cloud computing (CloudCom) and is crucial to its economic growth.

CloudCom is a distributed computing model that offers highly reliable and scalable services to subscribers. Emerging technologies, including Vehicular Adhoc Network (VANET) (Whaiduzzaman et al., 2013), Wireless Sensor Networks (WSN), and mobile computing applications (e.g., online games, bio-medical image processing, etc.) (Khan et al., 2013) use cloud-hosted services (e.g. infrastructure as a service (IaaS), platform as a service (PaaS) (Kremer; Mell and Grance, 2011), and Software as a service (SaaS)) to improve and extend functionalities. For instance, Vehicular cloud computing (VCC) merges VANET and CloudCom to assist vehicle drivers to minimize traffic congestion, accidents, and travel time (Huang et al., 2014; Whaiduzzaman et al., 2013). Similarly, a sensor cloud merges WSN and CloudCom to improve remote healthcare, vehicular transport systems (VTS), and environmental monitoring (Kim et al., 2014; Wang and Fan, 2014, Whaiduzzamanet al., 2013) by exploiting cloud services. Virtualization technology, the backbone of CloudCom, proactively offers scalable services to customers

Virtualization employs a hypervisor to proficiently manage several VMs running on a single physical server and to efficiently utilize cloud resources (Barham et al., 2003, Bugnion et al., 2012; Tao et al., 2012; Younge et al., 2011). However, co-hosting multiple VMs degrades application performance due to high resource contention (Asberg et al., 2011; Habib, 2008; Hu et al., 2013; Nathan et al., 2013; Younge et al., 2011). To improve application performance, the migration daemon migrates VM(s) to a resource-rich server in order to reduce the degree of resource contention (Jeong et al., 2013; Shuja et al., 2012; Mishra and Jaiswal, 2012; Moura Silva et al., 2007; Pop et al., 2012; Yao et al., 2014). However, since VM migration is a resource-intensive process, application performance is significantly affected during migration (Barhamet al., 2003; Clark et al., 2005; Xu et al., 2014). Bandwidth optimization techniques such as deduplication, compression, write-throttling, and dynamic rate-limiting optimize bandwidth utilization efficiency to enhance application performance (Deshpande et al., 2012; Gerofi et al., 2011, Hirofuchi et al., 2010; Sahni and Varma, 2012; Svärd et al., 2011). Furthermore, VM migration techniques migrate VMs either within LAN or WAN boundaries. However, while VMs migrate over WAN links, the migration daemon migrates storage besides VM memory. To optimize power consumption, VM migration technology uses server consolidation frameworks to switch off unnecessary servers (Deshpande et al., 2012).

This paper comprehensively reviews current VM migration schemes in cloud data centers and identifies challenges with migrating VMs across CDCs. The issues are thoroughly investigated while consolidating servers, and optimizing network bandwidth, storage, and dynamic voltage frequency scaling (DVFS)-enabled power consumption. We meticulously review VM migration schemes and underline their strengths, weaknesses, and issues requiring further research. Novel thematic taxonomies for VM migration approaches for server consolidation and bandwidth optimization are proposed to classify existing literature. The critical aspects and significant features of existing VM migration techniques are inspected through qualitative and quantitative enquiries. We drive critical parameters from the literature to compare VM migration schemes for server consolidation, bandwidth, storage, and DVFS-enabled power optimizations methods. Finally, open research issues and trends in the VM migration domain necessitating further exploration to develop optimal techniques for VM migration in cloud data centers are discussed. The main contribution of this article lies in the categorization of frameworks/schemes based on thematic taxonomies, analysis of existing migration schemes by discussing implications and critical aspects, identifying issues in existing solutions, and highlighting recent trends in the VM migration domain.

The rest of this paper is structured as follows. Section 2 discusses CloudCom, VM migration, DVFS technology, and server consolidation method. Section 3 presents a thematic taxonomy for the classification of server consolidation frameworks, existing server consolidation frameworks, and comparisons of existing frameworks based on parameters selected from literature. Section 4 presents a thematic taxonomy on bandwidth optimization schemes, and discusses state-of-the-art bandwidth, storage, and DVFS-enabled power optimization, followed by a detailed discussion on comparisons of existing schemes. Section 5 briefly discusses the research issues and trends in the VM migration domain. Section 6 concludes the paper with a discussion on potential future research directions.

## 2. Background

This section briefly overviews cloud computing, virtual machine migration, server consolidation, and DVFS enabled VM migration process.

### 2.1. Cloud computing

A Data Centre (DC) consists of interconnected servers organized into racks that represent a tree-based model for efficient resource management (Mahajan and Singh, 2013). A DC provides the foundation for implementing CloudCom services to offer subscribers elastic services (Armbrust et al., 2010; Niranjan Mysore et al., 2009). DC operators offer cloud services (Mahajan and Singh, 2013) based on the “Pay as you go” service model, to drive professionals (e.g., researchers, businessmen, etc.) to profoundly exploit cloud services (Buyya et al., 2010). The SaaS service model