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Review

Application partitioning algorithms in mobile cloud computing: Taxonomy, review and future directions

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A B S T R A C T

Mobile cloud computing (MCC) enables the development of computational intensive mobile applications by leveraging the application processing services of computational clouds. Contemporary distributed application processing frameworks use runtime partitioning of elastic applications in which additional computing resources are occurred in runtime application profiling and partitioning. A number of recent studies have highlighted the different aspects of MCC. Current studies, however, have overlooked into the mechanism of application partitioning for MCC. We consider application partitioning to be an independent aspect of dynamic computational offloading and therefore we review the current status of application partitioning algorithms (APAs) to identify the issues and challenges. To the best of our knowledge, this paper is the first to propose a thematic taxonomy for APAs in MCC. The APAs are reviewed comprehensively to qualitatively analyze the implications and critical aspects. Furthermore, the APAs are analyzed based on partitioning granularity, partitioning objective, partitioning model, programming language support, presence of a profiler, allocation decision, analysis technique, and annotation. This paper also highlights the issues and challenges in partitioning of elastic application to assist in selecting appropriate research domains and exploring lightweight techniques of distributed application processing in MCC.

Contents

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1. Introduction

The development of mobile computing and cloud computing technologies has drastically changed the current perspective on distributed computing. Smart Mobile Devices (SMDs) such as smartphones and tablets Personal Computers (PCs) have become convenient and essential tools of daily life for communication and complicated pervasive mobile applications (Dinh et al., 2011; Prgomet et al., 2009; http://drive.google.com; http://office365.microsoft.com; http://www.onlive.com/; http://mail.google.com). SMDs are predicted to be the essential computing devices in the near future with high user expectations for accessing computational intensive applications analogous to the powerful stationary computing machines (Shiraz et al., 2013b). However, applications on the latest generation of SMDs are still overshadowed by battery power, CPU potentials, memory capacity, wireless network bandwidth, and the intrinsic limitations in the mobile computing environment (Shiraz et al., 2013b, 2014; Kumar et al., 2012). Mobile cloud computing (MCC) mitigates resources limitations of SMDs by extending the services and resources of rich cloud datacenters. Cloud service providers use different service provisioning models such as Software as a Service (Greschler and Mangan, 2002; Vidyanand, 2007; Wei et al., 2008), Infrastructure as a Service (Bhardwaj et al., 2010; Prodan and Ostermann, 2009), and Platform as a Service (Keller and Rexford, 2010; Lawton, 2008) for providing access to the resources and services of computational clouds. Examples of cloud service providers include Amazon EC2 (http://www.amazon.com/ec2/), Microsoft Azure (http://www.microsoft.com/azure/), and Google AppEngine (http://appengine.google.com). MCC leverages the application processing services of computational clouds to resource-weak client devices. Recently, distributed application processing has been implemented to leverage the limitations of resources on SMDs by outsourcing the application processing load of mobile device to cloud server nodes entirely (Goyal and Carter, 2004; Liu et al., 2009; Satyanarayanan et al., 2009)or partially (Bialek et al., 2004; Cuervo et al., 2010; Giurgiu et al., 2009; Kumar et al., 2012).

Mobile applications need intensive interactions with other capabilities such as Global Positioning System (GPS) and camera, thus, it is also impractical to offload the entire application from SMDs to computational clouds (Pathak et al., 2011). Therefore, elastic applications are partitioned at different levels of granularity for distributed application processing — application partitioning is used to separate the intensive components of the mobile applications which operate independently in the distributed environment. However, runtime partitioning of elastic applications involves additional computing resources to implement runtime application profiling and solving. This makes partitioning of elastic application challenging because the mechanism requires minimal resources utilization and energy consumption cost on mobile devices (Bialek et al., 2004; Cuervo et al., 2010; Giurgiu et al., 2009; Abebe and Ryan, 2011; Park et al., 2014).

A number of recent studies have highlighted the different aspects of MCC (Abolfazli et al., 2014b; Shiraz et al., 2013a,b; Abolfazli et al., 2014a; Sanaei et al., 2014; Gani et al., 2014). Yu et al. (2013) studied application mobility in pervasive computing, which classifies and compares mobile application frameworks along with the four dimensions of design concerns in application migration. Their findings provide a systematic reference for developers to leverage different migration strategies for seamless application mobility. Fernando et al. (2012) reviewed previous researches on MCC and proposed a taxonomy for key issues in MCC — operational, end user, service levels, security, and context awareness issues — for accessing cloud services. Similarly, Dinh et al. (2011) highlighted different research domains of MCC and provided an overview of the MCC including the definition, architecture, and applications. Current studies, however, have overlooked into the mechanism of application partitioning for MCC. We consider application partitioning to be an independent aspect of dynamic computational offloading and therefore we review the current status of application partitioning algorithms (APAs) to identify the issues and challenges. The techniques used are categorized based on thematic taxonomy, and the implications and crucial issues of these techniques are analyzed. The similarities and differences of current APAs are compared based on partitioning granularity, partitioning objective, partitioning model, programming language support, profiler, allocation decision, analysis technique, and annotation.

The key contributions of this paper are the following: (a) proposing a taxonomy for classification of partitioning algorithms for distributed applications processing for mobile cloud computing; and (b) analysis of the current techniques based on relevant parameters to identify the issues which impede optimization goals of distributed application processing in MCC.

The paper is organized into the following sections. Section 2 discusses the fundamental concepts of cloud computing and MCC, elastic applications, and application partitioning for distributed application processing. Section 3 describes the thematic taxonomy of current APAs, reviews current partitioning algorithms based on taxonomy, and the implications and critical aspects of current partitioning algorithms. It also presents an analysis of current APAs based on selected parameters presented in the taxonomy. Section 4 highlights the issues and challenges in partitioning elastic application for MCC. Section 5 focuses on discussion, gap analysis, and future trends. Finally, Section 6 concludes the paper and suggests the directions for future research.

2. Background

This section presents the fundamental concepts of cloud computing and MCC, and explains the theoretical aspects of application partitioning and distributed application processing for MCC.