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Dynamic energy-aware cloudlet-based mobile cloud computing model for green computing

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ABSTRACT

Employing *mobile cloud computing* (MCC) to enable mobile users to acquire benefits of cloud computing by an environmental friendly method is an efficient strategy for meeting current industrial demands. However, the restrictions of wireless bandwidth and device capacity have brought various obstacles, such as extra energy waste and latency delay, when deploying MCC. Addressing this issue, we propose a *dynamic energy-aware cloudlet-based mobile cloud computing model* (DECM) focusing on solving the additional energy consumptions during the wireless communications by leveraging *dynamic cloudlets* (DCL)-based model. In this paper, we examine our model by a simulation of practical scenario and provide solid results for the evaluations. The main contributions of this paper are twofold. First, this paper is the first exploration in solving energy waste problems within the dynamic networking environment. Second, the proposed model provides future research with a guideline and theoretical supports.

1. Introduction

Mobile cloud computing (MCC) is an emergence of multiple Internet-based technologies development, which enables mobile users to acquire benefits of cloud computing and achieve green computing by using their mobile devices (Sabharwal et al., 2013; Bonino et al., 2013). The technology mainly derives from three hemispheres, including mobile computing, mobile Internet, and cloud computing. Combing the advantages of multiple techniques allows users to offload data processing and storage to the cloud-based servers (Huang et al., 2011; Kumar and Lu, 2010). However, behind the benefits of adopting this approach, the implementations of MCC are still facing a few challenges that limit its performance, such as energy over consumptions while the wireless communications are weak (Guan et al., 2011). Keeping searching wireless signals can dry out the power of mobile devices, which may cause unexpected energy waste (Han et al., 2011).

In this paper, we propose an advanced dynamic model, *dynamic energy-aware cloudlet-based mobile cloud computing model* (DECM), which uses *cloudlets* technique to assign, manage, and optimize the cloud-based infrastructure usages and services for achieving green computing. This model uses dynamic programming to assist cloudlets cloud computing resources within a changing operational environment. The intention of DECM matches practical demands of mobile industry because various elements can have major influences on the cloud services quality. For example, mobile users who are using map services highly rely on the speed of wireless communications while the mobile devices are rapidly moving. Nevertheless, unstable and inefficient wireless connections usually shorten the battery life.

Many researchers and scholars have done various achievements in energy-aware mobile cloud computing in previous research. The research is diverse in different perspectives (Gupta and Roy, 2013). Zhu and his team (Yang et al., 2014) developed a real-time tasks oriented virtualized cloud computing system that was designed to achieve energy-aware scheduling in their recent works. The proposed solution (Yang et al., 2014) intends to integrate various energy-aware scheduling algorithms by employing a rolling-horizon optimization policy. However, this approach did not consider mobility usage and the similar research focusing on energy-aware cloud computing systems has been accomplished by other scholars (Mezmaz et al., 2011; Beloglazov and Buyya, 2010; Berl et al., 2010).

Furthermore, as one of the core techniques in cloud computing, virtual machine (VM) is considered an efficient approach for building up cloud-based datacenter to achieve green computing

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(Aksanli et al., 2012). Nevertheless, VM is only a service representation approach that does not bring much technical innovations, even though VM has been broadly applied in deploying green *Information Technology* (IT) industry, such as green data processing, storage, and transmissions (Baliga et al., 2011; Lee and Zomaya, 2012; Xiao et al., 2013).

Based on the industrial needs, our advanced deployment model, DECM, offers a unique mechanism to avoid the energy waste when users are suffering a complicated and unstable networking environment. The model is a type of web service that focuses on efficient communications between user devices and cloud servers. Figure 1 represents a conceptual model of DECM. Three main components of DECM include mobile device, cloudlets with dynamic searching, and cloud computing. The relationship between cloudlet and dynamic searching is that the cloudlets provide an operating platform in which the dynamic search is executed.

The procedure of the service delivery is followed by the directions of the arrows. Mobile devices send the service requests to the closest cloudlets before the requests reach the cloud servers. The cloudlets allocate the cloud servers for better service performance determined by a group of constraints, such as nearby server locations or networking stability. Dynamic programming is applied in cloudlets for adapting to the constant changing context. Selecting the best solution directed by the dynamic-based cloudlets is the core component of DECM, which is expected to avoid energy waste when switching cloud servers or wireless networks.

We develop a motivational example explaining the fundamental methods of adopting DECM. The implementation of the example is a simulation followed by the proposed model. Figure 2 illustrates the fundamental concepts of DECM. Compare with classic web services, business logics are refereed by cloudlets that use dynamic programming to search efficient cloud services. This difference is a core session in our model, which is optimizing the utilizations of cloud resources in mobile cloud. Detailed information of fundamental concepts for DECM is given in the following section.

The main contributions of this paper are twofold.

1. This research is the first attempt on the functionality of cloudlets in order to achieve energy-aware performances in the dynamic networking environment.
2. The results of this research provide theoretical supports and explorations. The model may be migrated and applied in multiple domains. The model may be able to be migrated and applied in multiple industries, which requires further research for identifying and proving.

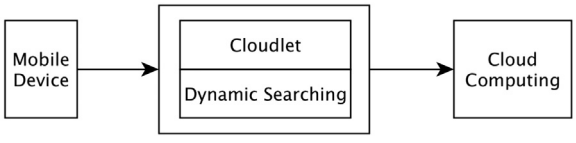

Fig. 1. A high level conceptual model of DECM.

The remainder of this paper is follows. We provide explanations about DECM in Section 2. Following the description of the model, an example is given in Section 3 in order to demonstrate the implementation of DECM in practice. Section 4 proposes and evaluates DECM algorithm. The experimental results are represented in Section 5. The conclusions are given in Section 6.

2. Concepts and model

2.1. Green computing

The principle of DECM can enable green computing because the model is designed for mainly reducing energy consumptions, which matches one of the characteristics of green computing as an energy-aware feature (Beloglazov et al., 2012; Mukherjee et al., 2014). The approaches of achieving green computing are from software and hardware to management, policy, and legal issues. Our model focuses on technical side that leverages a few cloud-related techniques, such as VM, wireless networks, and dynamic programming.

Using our proposed schema can reduce the energy consumption in wireless communications. The system reliability is also considered in the proposed schema, which aims to guarantee the performance of the system. Saving the energy costs of the communications can achieve green computing. The goal of performing green computing is to apply DECM to reduce energy consumptions on mass mobile devices without weakening the performance of cloud services.

2.2. Mobile cloud computing

MCC is the conceptual architecture that combines three technologies, including mobile Internet, mobile computing, and cloud computing, to enable mobile users to offload data processing and storage onto clouds via wireless networks and mobile devices (Dinh et al., 2013; Kumar and Lu, 2010; Guan et al., 2011; Song and Su, 2011). The motivation of applying MCC is gaining benefits of cloud computing technologies by leveraging mobile techniques. The dynamic networking environment results in more complicated service deployments and implementations, comparing with basic cloud computing.

The first basic part of MCC is *mobile Internet*, also known as *wireless networks*, that is a series of computing networks for achieving wireless communications by connecting network nodes and using wireless protocols. A variety of mobile Internet techniques are available for different demands (Chan et al., 2011). Main techniques of wireless networks include *wireless personal area networks* (WPAN), *wireless local area networks* (WLAN), *wireless metropolitan area networks* (WMAN), *wireless wide area networks* (WWAN), and cellular networks. Among these techniques, the cellular network is an approach of deploying wireless communications, such as 3G and *long-term evolution* (LTE).

Moreover, supported by mobile Internet, *mobile computing* (Satyanarayanan, 2011) is a group of techniques for executing wireless communications on both software and hardware sides, such as mobile

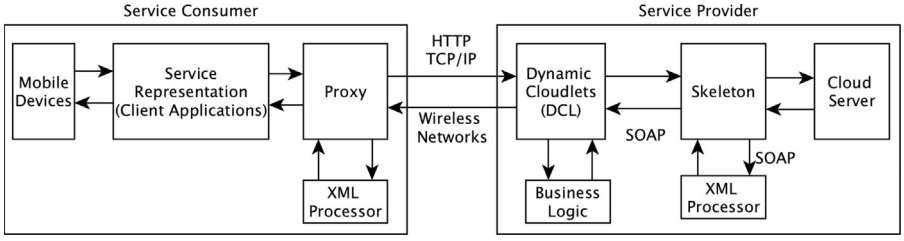

Fig. 2. Fundamental concepts for DECM.