Mobile cloud computing

Rerohit Kumar

IEEE COMSOC Multimedia Communications ...

Mobile Cloud Computing

Dijiang Huang
Arizona State University, Arizona, USA
dijiang@asu.edu

1. Introduction

Mobile cloud computing is an emerging cloud service model following the trend to extend the cloud to the edge of networks. It includes numerous mobile devices that are closely associated with their users. They will be directly involved in many cloud activities that extend the cloud boundaries into the entire cyber physical system. As predicted by Gartner, mobile phones will overtake PCs as the most common Web access devices worldwide by 2013 [1]. Thus, mobile devices will become more important and will be involved in almost all aspects of our daily life.

In this letter, we describe what is mobile cloud computing, including its scope, current developments, and research challenges. Our discussion is based on a mobile cloud computing platform that is currently developing at Arizona State University [2]. Then we present applications relying on mobile cloud computing. Finally, we conclude this article.

2. What is mobicloud computing?

Mobile computing research is to study how portable devices sense and learn the status of devices and the context related to their mobility and networking in order to better support mobile applications in an ad hoc communication environment. Cloud computing research mainly focuses on how to manage computing, storage, and communication resources that are shared by multiple users in a virtualized and isolated environment (NIST provides a more completed definition of cloud computing in [3]). Mobile cloud computing cannot be simply illustrated as merging mobile computing and cloud computing technologies.

An illustrative example of mobile cloud computing is how a smart phone can best utilize the cloud resource to reduce its energy consumption. A computing task can be either executed on the mobile device or outsourced to the cloud. Where to compute depends on the overhead tradeoffs between computation and communication while considering the requirements of applications' Quality of Service (QoS) and users' Quality of Experience (QoE) [4]. On one hand, the dual computing model involving both the cloud and the mobile device should minimize the entire system cost, usually with more focus on reducing resource consumptions on mobile devices. On the other hand, a mobile cloud computing service model should improve mobile users' QoE to fulfill their satisfaction when using mobile cloud applications. To address the aforementioned issues, researchers need to have a comprehensive view of mobile cloud computing. If research is limited to within each individual research domain, it will not be sufficient enough to address complex problems arising from the new mobile cloud service model.

Transdisciplinarity of mobile cloud computing research: Mobile cloud computing originally is rooted from interdisciplinary research of mobile computing and cloud computing. Existing research tries to cross the disciplines' boundaries by applying cloud computing solutions into mobile applications or incorporating mobile features when constructing new cloud services. However, the immense information involved in mobile cloud applications and the high complexity of designing mobile cloud applications demanded a new transdisciplinary research to better understanding the natures and principles of mobile cloud computing. We call this new transdisciplinary research as mobicloud computing. To simplify the presentation in the following context, the term mobicloud is more frequently used.

One important feature of mobicloud applications is functional collaboration. For example, mobile social network based data mining requires collaborations among mobile users. To this end, mobicloud will serve as not only a nexus that interconnects information sources gathered from both cloud computing service domain and mobile computing domains, but also a knowledge center to help mobile users in their daily activities.

IaaS delegation: Mobicloud infrastructure can be established in a bottom-up fashion based on an Infrastructure-as-a-service (IaaS) [3] framework. IaaS provides isolations at the Virtual Machine (VM) level. One or multiple VM(s) can be dedicated to a mobile device providing computing, communication, and storage support. Many operations that are not suitable to run on a mobile device, such as multimedia data processing or data mining, can be performed in its dedicated VM. We call this feature of mobicloud infrastructure as IaaS delegation.

NaaS intra-mobicloud service model: Current IaaS systems lack support to establish a flexible and secure virtual networking environment that can be initiated and managed by mobile users. For example, private data (e.g., pictures, video clips, etc.) can be shared among trusted users through their mobile devices. Based on IaaS delegation, the sender can transfer the data into his/her dedicated VM(s), where the data can be shared among all VMs dedicated to trusted data receivers. Since mobile users can control and operate their dedicated VM(s) within the cloud system, it is desirable that the mobicloud protects the transmitted data. An obvious solution is to establish virtual private networks (VPNs) among VMs within the mobicloud system. Based on existing Open vSwitch solutions [5] at the hypervisor level and OpenFlow switches [6] at the physical network level, VLANs (Virtual LANs) can be deployed to build the intra-mobicloud VPNs.

The software controlled feature of vSwitch and OpenFlow switch enables mobicloud to establish a VLAN-based VPN management framework. Compared to traditional VPN solutions, mobicloud allows VLANs to be established in an ad hoc fashion. Additionally, mobicloud needs to address the need for a large numbers of VLANs with traffic engineering capability that provides bandwidth guarantee to support the application layer intra-mobicloud communication sessions. We call this on-demand network system provisioning as Network-as-a-Service (NaaS) for mobicloud. The described VLAN capability is important for mobicloud computing since inter-VM communication can dominate mobicloud applications. This is fundamentally different from existing remote computing and storage provisioning based cloud applications.

Mobicloud PaaS platform: The described IaaS delegation and NaaS mobicloud service model are restricted by its low-level realization that usually creates a high-level learning barrier for mobicloud application developers. To overcome this software development hurdle, Platform-as-a-Service (PaaS) [3] must be established to provide a standard Application Platform Interface (API). The main challenge in establishing mobicloud PaaS is the compatibility issue among many mobile operating systems in the current market, e.g., Andriod, iOS, Windows 7, Symbian, etc. A general application platform is required to integrate the IaaS delegation and NaaS service model to support different mobile application platforms. To this end, we propose an XMPP [7] plus OSGi [8] (i.e., Extensible Messaging and Presence Protocol plus Open Services Gateway initiative) solution. XMPP is a set of open technologies provided as a lightweight middleware solution to coordinate the operations among mobicloud components. It also supports multimedia data transmissions and presence services that can be easily integrated as general interfaces for mobicloud PaaS. By interfacing with XMPP, OSGi provides multi-platform supported java programming capabilities. Standard OSGi bundles supporting mobicloud basic functions can be created as a software development kits for easier programming. Distributed OSGi allows mobicloud to run applications in a distributed fashion to balance performance and energy consumptions of mobile devices.

High QoE for mobile users: In mobicloud, QoE measures the subjective feeling of mobile users' experiences when using mobicloud based applications. QoS objectively measures the services such as communication delay, throughput, etc. QoS usually has a strong impact on QoE. However, a better QoS measurement does not mean improved QoE. For example, running powerful CPU on mobile devices may improve the performance of applications; however it may also shorten the device's use time due to high power consumption that will decrease users' QoE. If migrating computing tasks to the cloud is a solution to address the high energy consumption, mobicloud service model needs to consider the trade-offs caused by migration delay, communication overhead, and power consumption due to the migration. Thus, mobicloud needs to consider the relationship between QoS and QoE as a measurement to evaluate the performance of the cloud system. We call this measurement as QoSE.

To improve QoSE, mobicloud should adopt a geography-based service model (or geo-based model). This is because mobile users can access the cloud services from any location in the world. The geo-based model can push the cloud service nodes to the mobile device as close as possible. In this way, service delay, which is a major QoSE measure, can be greatly reduced. The geo-based model requires mobicloud server nodes (or clusters) to mirror VMs (or through VM migration) in different geographic locations. The states of the mirrored VMs must be synchronized.

Context awareness between a mobile device and its dedicated VM(s) is another important feature to improve QoSE. Nowadays, a smart mobile device usually serves as an information gateway for the mobile user involving many personalized activities such as checking emails, making an appointment, surfing the web, calling a number, locating some interested spots, etc. Context awareness can be at either the device level or the application level. When it is at the device-level, the device's states such as CPU utilization, available memory and storage, and battery levels need to be learned by its VM to decide whether computing operations should be migrated or not. At the application level, mobile devices can be interfaced to various wireless-capable devices such as sensors, RFIDs, and other smart devices. Mobicloud will serve as a knowledge base to instruct mobile devices on how to locate them and interface with (or control) them? Without the support of mobicloud services, these tasks are difficult to be executed by individual mobile devices. Each mobile device can be considered as a sensing service node for the cloud. The number of mobile devices involved determines the quality of mobicloud services that utilize sensed data. This situation requires us to investigate two critical mobicloud features: security and privacy.

User-centric security and privacy: Mobicloud must be user-centric, i.e., mobile users should have the privilege to manage their own data in the cloud. The trust model of existing cloud service is one-way (or cloud-centric), in which users must trust the cloud services when managing users' data in the cloud. This cloud-centric trust model prevents many users from using cloud services and storing their critical data in the cloud's storage. To address this problem, we propose to build a user-centric trust model for mobicloud. The user-centric model incorporates a tri-rooted VM management model including user root, maintenance root, and auditing root. The user root has the root privilege to manage all security and data storage related functions. The maintenance root performs regular maintenance tasks including networking, software upgrade, and regular cloud resource management for VMs. The auditing root does not have privileges of change, write, or execute in the VM. Instead, it maintains a log to record the VM activities that can be viewed by both the end users and cloud administrators for investigating issues such as misuse of the cloud system and ineligible access to user's data, etc.

2. Mobicloud applications

Mobicloud is a cloud service platform supporting many mobile application scenarios. Here, we just name a few: mobile health, mobile learning, mobile banking, intelligent transportation, smart grid/home, mobile advertising, urban sensing, disaster recovery, mobile entertaining/gaming, mobile social networks, and mobile enterprise solutions. These mobile applications scenarios share some common features that we have discussed previously, which are summarized as follows:

- User-centric security and privacy protection: A major incentive for mobile users using mobicloud applications is to protect users' data and allow them to decide what information could be exposed and what information should be kept as secrets.
- Individual and collective sensing capability: Mobicloud applications can utilize the sensing capabilities from each mobile device to learn the context of a given application situation.
- Personalized functions and features: A mobile device serves as a personal information assistant to help mobile users to learn his/her activities and behaviors. These past learned activities and behaviors can help mobile users to correct their bad habits and assist their daily activities.
- Strong reliability and fail-over protection: Damage and loss of mobile devices are common due to their small and portable nature. Mobicloud provides a suite of solutions to protect the mobile users' data and provide data recovery it due to failure, lost (or stolen), and upgrade.
- Rich software development platform: The integrated IaaS delegation and PaaS features allow mobicloud application developers to

develop various applications enjoying all features provided by mobicloud. Moreover, it is easier to integrate various applications in the mobicloud system with little compatibility issue.

- Function, data, and trust presence: Dedicated VMs are present 24/7. Functions, data, and trust validations of mobile applications can be delegated to the VMs even if mobile devices and mobile users are not reacheable.
- Caching capability: Mobicloud can help mobile devices maintain the states of mobicloud applications. Partially delivered data, lost connections, and half operated functions can be resumed; as a result, this will reduce the overhead due to the uncertainty caused by the mobility of mobile users.

3. Conclusion

In this article, we describe mobile cloud computing, a new transdisciplinary research area based on traditional mobile computing and cloud computing. The description is based on the current development of the mobicloud system at Arizona State University. We lay out the design features of mobicloud and its capabilities to assist modern mobile applications. Several critical research issues are presented to highlight our on-going and future work. We hope this article will help interested researchers and system builders develop new mobicloud features and get a better understanding of the transdiciplinary nature of the research in mobile cloud computing.

References

[1] Mark Walsh. Gartner: Mobile To Outpace Desktop Web By 2013. Online Media Daily, January 13, 2010.

[2] Secure Networking And Communication (SNAC) Research Group, MobiCloud Project, available at http://mobicloud.asu.edu, Arizona State University, 2010.

[3] Peter Mell and Timothy Grance. The NIST Definition of Cloud Computing (Draft). January, 2011.

[4] Ramesh Jain. Quality of experience, IEEE Multimedia, vol. 11, no. 1, pp. 96–95, 2004

[5] Ben Pfaff, Justin Pettit Teemu Koponen, Keith Amidon, Martin Casado, and Scott Shenker. Extending Networking into the Virtualization Layer, HotNets-VIII, Oct. 22-23, 2009.

[6] OpenFlow Switch Specification. Version 1.1.0 Implemented, February 28, 2011.

[7] Peter Saint-Andre. Extensible Messaging and Presence Protocol (XMPP): Core. IETF RFC 3920, Oct. 2004.

[8] OSGi Alliance. OSGi Service Platform Core Specification, Release 4, Version 4.3, April 2011

Dijiang Huang received his B.S. degree from Beijing University of Posts and Telecommunications, China 1995. He received his M.S., and Ph.D. degrees from the University of Missouri—Kansas City, in 2001 and 2004, respectively. He joined Arizona Sate University as Assistant Professor in 2005. He is currently an associate professor in the School of Computing Informatics and Decision System Engineering at the Arizona State University.

His current research interests are computer networking, security, and privacy. He is an associate editor of the Journal of Network and System Management (JNSM) and an editor of IEEE Communications Surveys and Tutorials. He served as an organizer for many International conferences and workshops. Dr. Huang's research is supported by NSF, ONR, ARO, Consortium of Embedded System (CES), and HP. He is a recipient of ONR Young Investigator Award 2010.