A Survey of Computational Offloading in Mobile Cloud Computing

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***Abstract*—**With the rapid development of mobile cloud computing (MCC), the computational offloading in MCC arises. This paper focuses on the computational offloading topic in MCC. It analyzes the existing research, discusses computational offloading decisions, gives a simple comparison of computational offloading framework, and reviews the data offloading in the big data environment. Finally, the issues and challenges on the computational offloading in MCC are examined.

Keywords*—mobile cloud computing, computational offloading decision, computational offloading framework, big data offloading*

I. INTRODUCTION

In the latest several years, the hardware and software of smart mobile device (SMD) have received the revolutionary development. However, the rapid increasing of variety mobile applications (such as natural language translators, image processors et al.) require higher computing power, memory, and battery power, and SMD shows low-potential capability for the computationally intensive applications. Fortunately, the development of mobile cloud computing (MCC) provides software-level solutions for mitigating resource constraints in SMD.

MCC is the latest distributed computing model which extends utility computing vision of computational clouds to SMD and utilizes the application processing services of computational clouds for the processing of computationally intensive applications. Nowadays, there are many researches for computational offloading. However, many of them are based on the classic distribute computing model. Karthik et al. [1] review some of computational offloading decisions which include improving performance and saving energy for mobile systems. Thus, we focus on the performance of the computational offloading in MCC: the feasibility of making offloading decision, the high efficiency of computational offloading framework.

This paper presents and classifies the key features of computational offloading. The major motivation is sharing our observations for the future trend on computational offloading in MCC. Section 2 discusses the computational offloading in MCC environment and analyses the data offloading in big data environment. Section 3 examines the issues and challenges in MCC. Section 4 gives the conclusion.

II. COMPUTATIONAL OFFLOADING IN MCC

A. Computational offloading decisions

Computational offloading migrates computation to a more resourceful cloud, it needs to make a decision to regard whether and what parts of computation could be migrated to cloud. In order to make an efficient decision, we should consider two aspects which include offloading method and factor. The offloading methods mainly contain static and dynamic, and the offloading factors include application partition scheme, mobile data traffic, application offloading, energy performance, secure and privacy protecting. Based on the computational offloading factors, we give a simple flow for the processing of computational offloading.

Firstly, elastic mobile application executes on SMD, if the computing resources can not satisfy the requirements of the application, the computational offloading mechanism is activated. Secondly, upon computational offloading factors, we make offloading decision. For example, if there are some sensitive and private data which can not be protected enough or cloud server is unbelievable, the part of computation should not be offloaded. Then, SMD negotiate with cloud servers for the selection of an appropriate server node. Finally, upon successful execution of the remote components of the application, the result is returned to the main application running on the SMD.

B. Computational offloading framework

Recently, many computational offloading framework (COF) are proposed for the processing of computationally intensive applications in MCC. According to the researching about state-of-art COF, we summarize four principle characteristics: multisite-spot, granularity level, privacy and security, offloading strategy. Multisite-spots include clone, cloudlet and mobile device cloud (MDC). Offloading strategies include virtual machine (VM) migration which means that SMD offload application by encapsulating the running application in VM instance, entire application migration means that SMD offload entire processing job to remote server nodes, application partition means that computational intensive components of the mobile are separated at run-time. Based on the characteristics, we give a simple comparison of computational offloading framework.

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TABLE I. **COMPARISON OF COMPUTATIONAL OFFLOADING FRAMEWORK**

Paper	Decision	Contributions	Multisite-spot	Granularity	Privacy and security	Offloading strategy
[2]	Dynamic	Propose a novel Energy Efficient COF which deploys a distributed architecture and employs lightweight procedure for minimizing the size of data transmission and energy consumption cost.	clone	component	no built-in security	application partition
[3]	Dynamic	Present a lightweight framework which employs centralized monitoring, high availability and on demand access services of computational clouds and reduce the turnaround time, the size of data transmission and energy consumption.	clone	method	no built-in security	entire application migration
[4]	Static	Present a framework for generating models to make automatic decisions using a genetic programming approach and design an convenient mechanism to evaluate the performance.	MDC/ clone	task	Considering privacy sensitivity	entire application migration
[5]	Static	Propose the framework to make an application autonomous and reduce the execution time and energy consumption.	clone	module	no built-in security	virtual machine migration
[6]	Dynamic	Present the Mobile Augmentation Cloud Services middleware which enables adaptive extension of Android application execution from a mobile client into the cloud and save energy.	cloudlet/ clone	module	no built-in security	application partition

C. *Big data offloading*

As the incoming of the big data era and the development of mobile cloud computing, it is significant for data offloading research. The authors of [7] propose the big data stream mobile computing based on broadband mobile internet networking and real-time mobile cloud computing, and it focuses on the real-time traffic offloading and the processing of big data streams acquired by resource limited mobile devices. What is more, the authors of [8] propose the scheme which can efficiently train deep computation model for big data feature learning by offloading the expensive operations to the cloud without disclosing the private data.

III. Issues And Challenges

There are many research issues and challenges for computational offloading in MCC. We will discuss them in three different areas: application partition granularity, security and privacy protection, infrastructure.

A. *Application partition granularity*

There are many issues associated with the different granularity levels of application partition such as compatibility, object identity, class unloading, state transfer and performance overhead. Finer partitioning granularity requires a highly intensive monitoring mechanism on the SMD at run-time, as well as an intensive synchronization mechanism between the SMD and the remote servers. Hence, it is hard to implement optimal granularity level for application partition which involves minimal communication overhead for component offloading and lightweight mechanism for the establishment and management of offloading strategy.

B. *Security and privacy protection*

This is an outstanding problem and the researches are still in primary stage. Major issues for computational offloading in MCC is the protection of location information and other personal sensitive information of users. The data stored in cloud may be read by the cloud service provider without the knowledge of data owner. In addition, the cloud provider may not be trusted by all means and there is a considerable chance of data being intercepted by an unauthorized user despite the safety measures undertaken by the cloud provider. Therefore, it is a challenge to realize the security and privacy protection of users for computational offloading in MCC.

C. *Infrastructure*

The infrastructures address various issues associated with the inter-operability, mobility and fault tolerance. Firstly, different types of resource constrained devices may interact and connect across different types of networks to one or many servers. Secondly, offloading may be possible between different systems of different computational capabilities. Thirdly, offloading relies on wireless networks and servers, however, the network may be congesting or failure and the server may be failure.

IV. Conclusion

This paper analyzes the existing research of computational offloading and gives a simple comparison of computational offloading framework in MCC. The issues and challenges on computational offloading in MCC are presented for future research.

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