Poster Abstract: A Multi-User Computation Offloading Algorithm based on Game Theory in Mobile Cloud Computing

Yujiong Liu, Shangguang Wang*, *Member, IEEE*, Fangchun Yang, *Senior Member, IEEE*
State Key Laboratory of Networking and Switching Technology
Beijing University of Posts and Telecommunications, Beijing, China
{yjliu, sgwang, fcyang}@bupt.edu.cn

***Abstract*—Mobile Cloud Computing (MCC) offers a new paradigm to relieve the pressure of soaring data demands and augment the capabilities of resource-poor mobile devices. In this paper, we study the multi-user computation offloading problem in MCC to reduce the total cost including energy consumption, time consumption and monetary cost on mobile devices. We formulate the computation offloading decision making problem among multiple mobile device users as a multi-user computation offloading game problem. We present a distributed computation offloading algorithm and show the existence of Nash equilibrium of the game. We show that the proposed algorithm can achieve efficient computation offloading performance.**

Keywords-Mobile Cloud Computing;Computation Offloading; Game Theory

I. INTRODUCTION

As mobile devices are gaining enormous popularity, advancements in computing hardware and communication technologies have enabled mobile devices to support more applications such as face recognition, interactive gaming and augmented reality. However, due to resource constraints to mobile devices' physical size and weight, in general, mobile devices have limited computation capacity and battery life, thus their desired performance cannot be achieved. The tension between resource-poor mobile devices and computation-intensive mobile applications poses a significant challenge for the mobile platform development [1].

To address the challenge, Mobile Cloud Computing (MCC) is envisioned as a promising solution. MCC is a promising system that introduces powerful cloud computing into a mobile computing environment, where mobile devices can offload the computation to the resource-rich cloud infrastructure through wireless network [2]. Liu et al. [3] proposed an adaptive multi-resource allocation strategy for cloudlet-based mobile cloud computing system and the strategy can adaptively allocate the optimal amount of wireless bandwidth and computing resource to the accepted user. Barbera et al. [4] studied the actual overhead in terms of bandwidth and energy to achieve full backup of both data/applications of a smartphone for mobile computation offloading purpose. Zhang et al. [5] developed an optimal offloading algorithm for the mobile user in an intermittently connected cloudlet system based on the users' local load and availability of cloudlet. Chen [6] proposed a decentralized computation offloading mechanism in a single-channel wireless setting. Cardellini et al. [7] provided a computation offloading strategy in a multi-user non-cooperative usage scenario. Chen et al. [8] studied multi-user computation offloading problem for mobile-edge cloud computing in a multi-channel wireless environment considering the communication and computation resources.

However, for latency-sensitive mobile applications with real-time constraints, offloading the computation to remote public clouds is insufficient, because mobile device users may experience long latency for data exchange with the remote public clouds. To address the challenge, a novel mobile cloud computing paradigm has been proposed, as illustrated in Fig.1. In this case, local cloud can provide powerful cloud-computing capabilities in close proximity to mobile device users. Moreover, the need for fast interactive response can be met by low-latency one-hop wireless connection to local cloud.

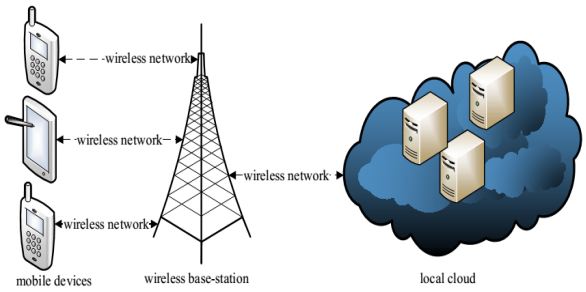

Figure 1. An illustration of mobile cloud computing.

Our motivation is that we study how to design an efficient computation offloading algorithm in MCC. Because most wireless networks are multi-channel, a key problem is how to achieve efficient wireless access coordination among multiple mobile device users to better support computation offloading. If a large number of mobile device users offload the computation to the cloud simultaneously sharing the same channel, they may reduce the data rate due to their mutual interference. Therefore, it can result in low energy efficiency and long time-delay. Moreover, it may incur a monetary cost for using cloud resources. In this case, it is not beneficial for mobile device users to offload the computation to a cloud server. To improve the performance of computation offloading and reduce the total cost in MCC, there are two key challenges: 1) how a mobile device user makes a decision whether to offload computation to a cloud server; 2) how to choose a proper channel for a mobile

device user to achieve high wireless access efficiency in a multi-user scenario.

II. Approach

We first introduce the system model that consists of communication aspects and computation aspects including energy consumption, time consumption and monetary cost for multiple mobile device users' computation offloading in MCC. Based on the system model, we consider the multi-user computation offloading problem as a centralized optimization problem and turn the centralized optimization problem into maximum cardinality bin packing problem. It is known that maximum cardinality bin packing problem is NP-hard, thus we can prove that it is NP-hard to obtain the optimal solution to the centralized optimization problem above.

Then we consider the multi-user computation offloading problem as a multi-user computation offloading game. We analyze the properties of the computation offloading game problem and show that the game is a potential game by constructing a potential function and prove that the game problem can achieve a Nash equilibrium. Moreover, we propose a distributed computation offloading algorithm that can achieve the Nash equilibrium of the multi-user computation offloading game and derive the upper bound of the convergence time. Furthermore, we quantify the efficiency ratio of the Nash equilibrium solution of the algorithm over the centralized optimization solution using price of anarchy.

Finally, we investigate the proposed distributed multi-user computation offloading algorithm by numerical experiments.

III. Conclusion

In this paper, we formulate the computation decision making problem among multiple mobile device users as a multi-user computation offloading game in MCC environment and prove that the game can achieve a Nash equilibrium. We also propose a distributed multi-user computation offloading game algorithm that can achieve a Nash equilibrium and analyze the performance of the algorithm. Performance evaluation shows that the proposed algorithm can achieve superior computation offloading performance.

References

[1] Cuervo, Eduardo, et al. MAUI: making smartphones last longer with code offload. In *Proceedings of the 8th international conference on Mobile systems, applications, and services*, pp. 49-62, ACM, 2010.

[2] K. Yang, S. Ou, and H.H. Chen. On effective offloading services for resource-constrained mobile devices running heavier mobile internet applications. *IEEE communications magazine*, 46(1): 56-63, 2008.

[3] Y. Liu, M. Lee and Y. Zheng. Adaptive multi-resource allocation for cloudlet-based mobile cloud computing system. *IEEE Transactions on Mobile Computing*, 2015. DOI=http://dx.doi.org/10.1109/TMC.2015.2504091.

[4] M. V. Barbera, S. Kosta, A. Mei and J. Stefa. To offload or not to offload? The bandwidth and energy costs of mobile cloud computing. *INFOCOM, 2013 Proceedings IEEE*, pp. 1285-1293. IEEE, 2013.

[5] Y. Zhang, D. Niyato and P. Wang. Offloading in mobile cloudlet systems with intermittent connectivity. *IEEE Transactions on Mobile Computing*, 14(12): 2516-2529, 2015.

[6] X. Chen. Decentralized computation offloading game for mobile cloud computing. *IEEE Transactions on Parallel and Distributed Systems*, 26(4): 974-983, 2015.

[7] V. Cardellini, V. D. N. Persone, V.Di. Valerio, et al. A game-theoretic approach to computation offloading in mobile cloud computing. *Mathematical Programming*, 157(2): 421-449, 2016.

[8] X. Chen, L. Jiao, W. Li and X. Fu. Efficient multi-user computation offloading for mobile-edge cloud computing. *IEEE/ACM Transactions on Networking*, 2015. DOI=http://dx.doi.org/10.1109/TNET.2015.2487344.