International Journal of Research

International Journal of Research (IJR)

e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 09, September 2015

Available at http://internationaljournalofresearch.org

Bandwidth Shifting and Redistribution in Mobile Clouds

Student: Badikala Spandana (13H66D5802)

Guide: A. Jyothi

(Assistant Professor) CVSR ENGINEERING COLLEGE

Abstract—

Mobile cloud computing (MCC) improves the computational capabilities of resource-constrained mobile devices. On the other hand, the mobile users demand a certain level of quality-of-service (QoS) provisioning while they use services from the cloud, even if the interfacing gateway changes due to the mobility of the users. In this paper, we identify, formulate, and address the problem of QoS-guaranteed bandwidth shifting and redistribution among the interfacing gateways for maximizing their utility. Due to node mobility, bandwidth shifting is required for providing QoS-guarantee to the mobile nodes. However, shifting alone is not always sufficient for maintaining QoS-guarantee because of varying spectral efficiency across the associated channels, coupled with the corresponding protocol overhead involved with the computation of utility. We formulate bandwidth redistribution as a utility maximization problem, and solve it using a modified descending bid auction. In the proposed scheme, named as AQUM, each gateway aggregates the demands of all the connecting mobile nodes and makes a bid for the required amount of bandwidth. We investigate the existence of Nash equilibrium (NE) in the proposed solution. Theoretically, we deduce the maximum and minimum selling prices of bandwidth, and prove the convergence of AQUM. Simulation results establish the correctness of the proposed algorithm.

Index Terms—Mobile cloud computing; auction theory; Nash equilibrium; bandwidth shifting; bandwidth redistribution

INTRODUCTION

MOBILE devices are increasingly becoming an essential part of our everyday life due to the rapid reduction in cost of hardware, improved portability, and increasing computational capability. The built-in data exchange feature in the modern mobile devices allows the users to run powerful web applications such as mobile banking, online gaming, video and image processing, online shopping, health management, and finance management. All these applications deal with real-time data streaming. Although the mobile devices have improved hardware and software, their limited energy source is a persistent problem. Consequently, executing computationally intensive applications on mobile devices remains a standing issue in mobile networks. MCC is an integration of cloud computing into the mobile environment. In MCC, the data processing and storing applications are moved from the mobile devices to the servers in a cloud, and, thus, improves the efficiency and lifetime of the mobile devices. In case of high computational resource and application requirements such as video streaming, audio, and data services, the mobile users request services from the cloud servers through an interfacing gateway. The gateway communicates with the cloud service provider (CSP) for allocating shared resources which are required for resolving the mobile user's request. Thereafter, connection is set up between the mobile user and the cloud server through the interfacing gateway, and, then, the mobile user is capacitated to use the resources of the cloud servers. At this juncture, we mention that the words "node", "device", and "user" are used interchangeably in the rest of the manuscript.

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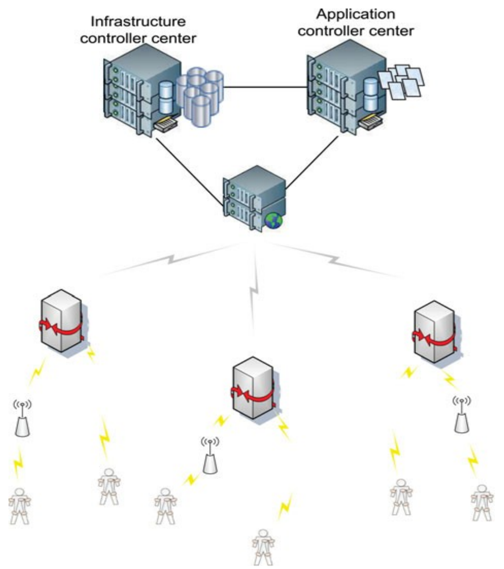

each gateway utilizes different percentages of allocated bandwidth from the CSP. Thus, bandwidth utilization of the previous interfacing gateway may differ from that of the current one. This difference violates the QoS requirement in the newly connected gateway, while the previous gateway can provide more QoS than its present requirement. Therefore, proper redistribution of bandwidth is essential in real-time applications for fulfilling the QoS requirements for computational services.

In this paper, we address the problems of bandwidth shifting and redistribution resulting from varying demand from gateways. It is pertinent to clarify at this juncture that the bandwidth redistribution problem differs from the traditional bandwidth allocation problem in that, a while the former concerns allocating proportional bandwidth to all the gateways (and, in turn, to the users), even if only a few gateways change their bandwidth demand, the latter concerns allocating bandwidth to that gateways who have changed the bandwidth demand. A schematic view of mobile cloud architecture . We do not consider the bandwidth allocation process between gateways and mobile nodes. We assume that the CSP is authorized for bandwidth shifting and allocation, and these functions are performed for the gateways only. In this work, we consider QoS-guarantee in terms of service delay.

There exist few allocation schemes that help to maintain QoS requirements of network nodes. For example, allocation schemes were proposed for ensuring maintaining equal expected access del, fair allocation , guaranteed bandwidth , delay guarantee , and service differentiation . For restricting the hand-off failure due to insufficient resource, a QoS-guaranteed measurement preservation scheme is proposed in . For achieving end-to-end fair bandwidth allocation, Tang

et al. proposed a max-min fair maximum throughput bandwidth allocation (MMBA) scheme followed by lexicographical max-min fair bandwidth allocation (LMMBA) scheme for wireless mesh networks integrated with cognitive radio. Fei et al. proposed a QoS guaranteed fair up-link dynamic bandwidth allocation algorithm for allocating bandwidth from base stations to relay stations in IEEE 802.16j-based vehicular networks. A hierarchical QoS-aware dynamic bandwidth allocation algorithm was proposed for assigning bandwidth depending upon the user requirements and weights of priority queue. Lin et al. addressed the problem of varying QoS requirement for different data incentive applications in cloud computing system.

Concurrently, dynamic spectrum allocation in cognitive\ radio networks (CRNs) is also an interesting resource allocation issue. Zhu et al. addressed the dynamic bandwidth allocation problem by building strategies using stochastic differential game for both the secondary users (SU) and the service providers (SP). Huang et al. proposed a spectrum sharing mechanism using an auctionbased approach keeping the ‘interference temperature’ under threshold. Chen et al. addressed the spectrum sharing problem for multi-licensed primary users (PUs) using auction theory. In their proposed framework, a licensed PU shares the unused spectrum to the unlicensed secondary user based on the interference temperature threshold of the PU of CRNs. In , three auction-based mechanisms were proposed for distributively allocating spectrum in CRN. They compared their own algorithms based on three characteristics—convergence, social welfare, and cheat-proof. A novel auction-based approach for sharing of dynamic spectrum in CRNs wa proposed, in which a PU is assigned the spectrum to the SUs based on the requirement of the SUs without violating its own performance.

Chaikijwatana and Tachibana investigated the problem of social surplus for efficient bandwidth allocation in wireless networks using generalized VCG auction mechanism with network coding. The authors considered that the total required bandwidth is always greater than the total available bandwidth. In , Kun et al. considered only the individual user performances for bandwidth allocation.

Many authors have also explored the bandwidth allocation problem in cloud computing scenario. In , a service level agreement-aware dynamic bandwidth allocator (DBA) is proposed in which the bandwidth is allocated among the virtual machines (VMs) for different application requirements associated with each VM. Papagianni et al. proposed a unified resource allocation framework for networked clouds. Das et al. considered the mapping of cloud server and mobile nodes in MCC environment. Similarly, many other works on bandwidth allocation exist in the literature. However, none of these addresses the problem of providing QoS-guaranteed bandwidth allocation in MCC environment, while the utility of each gateway is optimal. In this paper, we propose QoS-guaranteed bandwidth shifting and redistribution schemes using auction theory in MCC environment.

Auction Theory

In applied economics, auction theory is well known for modeling buying and selling of commodities and services. Similarly, auction theory is also useful for exchanging commodities in the network applications . Apart from other auctions such as Sealed-Bid, Open-Cry, First-Price,
and Second-Price , conventional auction is more popular in the context of exchanging network commodities due to its simplicity. Conventional auction is mainly classified into two categories based on the bidding schemes—ascending or descending bid auction.

BANDWIDTH SHIFTING

We consider a mobile cloud network. It may be stressed that the nodes are mobile in such environment. In this section, we theoretically prove that node mobility triggers the necessity of bandwidth shifting, if the cloud server does not have any unused reserved bandwidth for future use. Subsequently, we prove that bandwidth shifting alone is not always sufficient for providing QoS-guarantee.

Necessity of Bandwidth Shifting

When a mobile node changes its location, the corresponding gateway for maintaining connectivity with the cloud changes. Therefore, the aggregated bandwidth requirement for the gateway also changes. For maintaining QoS in terms of service delay, the present gateway checks the total transmission delay for all connecting nodes, and the allocated bandwidth. In Theorem (1), we prove that the modified service delay increases with node mobility.

Bandwidth Redistribution

Considering the same experimental settings, as described in we executed the AQUM algorithm. The redistributed bandwidth for each gateway .It is observed that the bandwidth allocation for gateways G3 and G4 gets changed due to change in the position of node N12. The redistribution mechanism also supports the service delay requirement of each gateway,

CONCLUSION

In this paper, we have identified and addressed the problem of bandwidth shifting and redistribution in an MCC environment. The bandwidth redistribution problem differs from traditional bandwidth allocation problem in that while the former concerns allocating proportional bandwidth to all the gateways (and, in turn, to the users), even if only a few gateways change their bandwidth demand, the latter concerns allocating bandwidth to that gateways who have changed the bandwidth demand. We have proposed an auction-based QoS-guaranteed utility maximization algorithm for maximizing the revenue of each gateway, while it maintains QoS of mobile nodes by purchasing bandwidth from the service provider. We have investigated the existence of NE and proved that the algorithm converges within a finite number of iteration. Even though the proposed algorithm, AQUM, maximizes the utility for performing the auction process, each gateway needs to know the bid value of others, which, in real environment, is not always feasible. A distributed algorithm, therefore, is necessary. Further, we have considered a random bidding increment within a range. Analysis on the selection of different bidding strategies and their implications on utility needs to be discussed in future.

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