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Pricing and resource allocation for multimedia social network in cloud environments

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ABSTRACT

Distributed resource allocation is critical for efficient sharing multimedia contents in cloud-based wireless multimedia social network environments. In this paper, a cloud-based multimedia service system architecture is proposed to overcome the limited bandwidth allocation problem in the context of social network, in which bandwidth limited mobile users are allowed to directly acquire live multimedia streaming from the desktop users rather than the cloud based on their social relationships. We also present a theoretical framework for bandwidth allocation from desktop users to mobile users by a dynamic resource pricing process in the proposed bandwidth management system, where price-sensitive users and QoS-sensitive users are considered, and all users target at maximizing their total utilities. Finally, an iterative allocation algorithm is designed to simulate the bandwidth allocation process with respect to shared bandwidth and price. Simulation results verify the effectiveness of our proposed pricing model and allocation algorithm in terms of convergence and efficiency.

1. Introduction

As wireless communication technologies evolved, the mobile devices such as smartphone, panel computer and personal digital assistant have experienced an explosive growth in recent years. By using these mobile devices, people are able to enjoy all kinds of multimedia contents wherever they want. However, higher demand for these multimedia contents always leads to the scarcity of storage and computation resource for both the users and content providers, which ultimately impacts the quality of service (QoS). Therefore, how to efficiently allocate resources has become a key challenge in managing the multimedia service networks [1].

With the wide application of cloud computing service [2–4], content providers prefer to cloud storage solution for their business applications by building cloud business systems. In addition, the emergence of multimedia social networks [5] encourages multiple users to share personal multimedia contents with their friends. Mobile users in multimedia social networks could obtain the multimedia contents from their nearby desktop users instead of the sole content provider. This mechanism is very convenient for both kinds of users. In this way, users easily obtain what they want with little cost, while the content providers also reduce the communication burden caused by large amount of users. Therefore, the scarcity of storage and computation resource for both the users and content providers in multimedia service networks can be easily overcome by integrating cloud service and social network into a cloud-based multimedia social network. Most of previous studies on P2P networks assume that all the users are homogeneous [6–8], that is, they are purely mobile users or purely desktop users. Actually, users in the same network are impossible to be completely homogeneous because they may differ greatly in bandwidth limit and access scheme, which thereby impacts the QoS of different users if they are treated equally. This paper considers two kinds of users (desktop users and mobile users) simultaneously competing resource in multimedia service networks. Obviously, if all the users obtain multimedia contents from content providers, it will be a big challenge for providers to supply high-quality multimedia contents services due to their limited bandwidth. Moreover, mobile users have to pay for live multimedia streaming and the content providers have to pay for extra bandwidth to telecom operators, which is not beneficial for either mobile users or content providers.

Besides, people with mobile devices always want to obtain internet resources from their nearby computers. For example, they wish to watch an online movie with their mobile phones by setting the computer as a hotspot via WiFi share software. In this paper, we address the problem of bandwidth allocation and propose a cloud-based multimedia service system (CMSS) to deal with the limited bandwidth problem. The proposed system allows mobile users to acquire live multimedia streaming from their desktop

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friends around them rather than the content provider. Besides, users are categorized based on their social contexts and have preference of sharing multimedia contents. To meet the objective of high-quality multimedia service, we also introduce a multimedia cloud that ensures a multimedia server delivers specific multimedia files to desktop users who are willing to share live multimedia streaming with their socially related mobile users. Therefore, the service cost for content providers and mobile users is greatly reduced, and the performance of multimedia contents distribution is improved simultaneously.

Nevertheless, as the number of mobile users increases, there arises another problem: how to efficiently allocate desktop users' bandwidth to mobile users. To achieve this, we build a virtual bandwidth allocation market, where desktop users supply a certain amount of bandwidth and each mobile user decides on choosing appropriate desktop user to connect for higher utility. First, each desktop user provides the size of its bandwidth and a reference bandwidth price, each mobile user sends its bandwidth request, and a bandwidth management system is introduced to handle the supplies of desktop users and demands of mobile users. In the system, the mobile users are divided into different groups and users in the same group can observe other users' connections, they always learn from other users' strategies. We also propose a dynamic pricing mechanism for efficient bandwidth allocation which is executed by the bandwidth management system located in a third-party platform. The purpose of the proposed pricing mechanism is to adjust the price that each desktop user issues and the connection that each mobile user chooses. Accordingly, a utility equilibrium is obtained when none of these users changes their connections or prices. Meanwhile, a bandwidth allocation algorithm [9] is designed to simulate the bandwidth allocation process, it can improve the utilities of all the desktop users during the process of pricing iterations and ensure the achievement of utility equilibrium for mobile users in the same group.

To summarize, there are three major contributions in this paper. First, a CMSS architecture is proposed to overcome the limited bandwidth allocation. Different from the traditional bandwidth allocation systems, the proposed CMSS allows bandwidth limited mobile users to acquire live multimedia streaming from the desktop users rather than the cloud. Meanwhile, an explicit business flow of CMSS is given to show how the multimedia contents are stored and scheduled, and how the multimedia files are transmitted from the content provider to all users. Second, a bandwidth management system is proposed to solve the bandwidth allocation problem, in which desktop users compete with each other and each mobile user alternatively chooses a desktop user by dynamic information interaction, and as a result, the bandwidth allocation result is obtained by our proposed algorithms. Third, a pricing mechanism is studied in the process of bandwidth allocation by considering price-sensitive users and QoS-sensitive users. In addition, numerical results indicate the proposed algorithms and the pricing mechanism are effective to improve the desktop users' utilities and to obtain a utility equilibrium for mobile users in the same group.

The rest of the paper is organized as follows. Section 2 briefly reviews existing related work. In Section 3, we give the business flow of CMSS and describe the dynamic bandwidth allocation process. Section 4 discusses the details of the pricing mechanism and iterative algorithm. We evaluate the performance of the proposed algorithm in Section 5. Finally, we conclude this paper in Section 6.

2. Related work

Previous work related to this paper consists of two main aspects, namely, multimedia social network and bandwidth allocation and pricing.

Multimedia social network [10,11] is studied in the traditional computer and communication literatures for nearly ten years. Zhang et al. focused on the study of developing a social norm to improve efficiency of multimedia sharing [10], which required that peers behave well to maintain their reputations. Considering security and privacy challenges in the process of multimedia contents transmission, Zhang et al. presented a model with a trust evaluation mechanism based on users' historical share information [11], and the authors in [12] proposed a MMSN framework, in which trust relationships are built among mobile users and malicious attacks are resisted. As we know, the concept of collaboration is widely used in many areas, such as collaborative filtering algorithm for recommendation system [13] and collaborative configuration of cluster supply chains [14]. User cooperation/collaboration is also applied in multimedia social network. In [15], users were divided into different groups according to their own preferences and a content ranker. This paper also proposed a cluster filtering mechanism to collect useful data for multimedia contents recommendation. Zhao et al. conducted their study from a unique position in [16], and modeled colluder dynamics in the multimedia social network as a game framework, they also gave a comprehensive analysis on colluders' utility functions and related parameters, which can help colluders make beneficial decisions and choose their partners. Besides, Rahman et al. presented a multimedia recommendation framework [17]. In the framework, services and social ties were first extracted and analyzed by using a personal social network extraction subsystem, and then proper services can be recommended to particular users in dynamic context. In [18], aiming at helping peers search for similar multimedia data in different scenarios, a flexible SWIM was designed.

However, the above studies mainly concentrate on exploring some common features and building mutually-beneficial cooperation in the whole social network community, and fail to investigate the social connections among different user communities for multimedia sharing. To solve the problem, this paper considers social features of mobile users and divides them into different groups, and investigates the information interaction among mobile users during the process of bandwidth allocation.

Bandwidth allocation and pricing [19–21] is always the focus of many researches being a core problem of network resource sharing. Niyato et al. proposed in [22] a pricing model for bandwidth sharing based on optimization, and introduced a genetic algorithm to obtain the nearly optimal solution when bandwidth demand is uncertain. In [23], a scalable bandwidth allocation strategy was designed to reduce blocking and maximize profit, the demand for bandwidth was estimated according to a curve based on special demand-price data in dynamic context. Since the historical information about bandwidth demand is useful for providers to establish users' performances, the authors in [24] presented a descending-price auction mechanism which allows users to bid several times for the same connection and gives the auctioneers a chance to optimize their profit. Some scholars conduct similar researches on bandwidth allocation with other efficient solutions. For example, a game theoretic model with an asynchronous algorithm by taking into account the fairness and rate control [25], and an approximate framework based on nonlinear-programming by using a real-time scheduling algorithm in the networked control systems [26]. EPON is considered as a promising research field and it is a challenge to allocate limited bandwidth resource over EPON architecture. In [27], Assi et al. developed a dynamic bandwidth allocation algorithm to meet differentiated requirements for QoS, in which the traffic behavior is studied and a priority queuing mechanism is introduced to alleviate the unexpected behavior. Another dynamic algorithm based on the concept of fairness and fuzzy logic was used to improve the