Foresighted Resource Reciprocation Strategies for Heterogeneous Multimedia Users in Peer-to-Peer Networks

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1. Introduction

Recently, numerous multimedia applications have been serviced over various network infrastructures such as wired networks (e.g., the Internet or local area network (LAN)), wireless networks, and overlay networks (e.g., peer-to-peer (P2P) networks). These heterogeneous networks are often resource constrained, and moreover, multimedia users may have different resource requirements. Therefore, it is important to design an adaptive resource management strategy while considering the characteristics of heterogeneous multimedia users.

In this article, we focus on the multimedia streaming users over P2P networks, where they have different quality of service (QoS) requirements and available resources (e.g., available bandwidth depending on each user's network connection). The most popular P2P protocol that is currently deployed in file sharing is BitTorrent [1]. However, it is known that the BitTorrent systems may not effectively cope with peers' non-cooperative behaviors such as free-riding [2], [3], leading to performance degradation. In order to overcome the limitation and improve the performance, a foresighted resource reciprocation strategy is proposed in [4], where peers with the foresighted resource reciprocation strategy can decide their resource reciprocations, such that they can maximize their long-term utilities, i.e., the immediate utility as well as the future utilities. This approach thus can lead to a better efficiency for resource reciprocation in P2P networks. However, the focus of these protocols is on efficient content distribution over P2P networks, without considering the timing constraints. Hence, these protocols can only provide a limited performance for multimedia streaming applications. A slightly modified BitTorrent protocol is designed for multimedia streaming, which is referred to as BiToS [5]. This protocol incorporates the packet (or data segment) selection process into the original BitTorrent protocol, thereby improving the multimedia streaming performance

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In this article, we enhance on the foresighted resource reciprocation strategy by explicitly considering the timing constraints for continuous display of the multimedia data and the importance of each multimedia data segment for the multimedia quality. In particular, priority functions are incorporated into the reward function in order to adapt to the specific characteristics of multimedia streaming applications. As a result, the peers exchange video packets with the strategy that ensures the most important packets have a higher probability to reach the decoder on time for proper decoding. Thus, the solution proposed for efficient file sharing can be enhanced to support the multimedia streaming.

2. Foresighted Resource Reciprocation Strategy for File Sharing

In [4], the resource reciprocation among peers that are interested in each other's content is modeled as a stochastic game, and the foresighted resource reciprocation strategy can be found in the Markov Decision Process (MDP) [6] framework. This model was originally proposed to replace the tit-for-tat and optimistic unchoke mechanisms in BitTorrent systems [1].

In general, the MDP consists of a set of states, a set of actions, reward function, and the state transition probability. The state transition probability determines a probability of mapping each state into the next state given an action. Specifically in [4], the MDP for P2P networks is modeled as follows. A state space of a peer represents a set of resources received from the associated peers in the peer set. An action space is defined as a set of actions that a peer can take in its peer set, which is the resource division of the peer. Reward for a peer represents received resources from its state. Finally, a reciprocation policy provides optimal actions for all states, and the policy can be obtained from a solution to the MDP. It is guaranteed that the policy can be obtained based on well-known methods such as value iteration and policy iteration. Note that solving MDP may require high computational complexity, which exponentially increases as more peers are considered in a peer set. Thus, it is necessary to reduce the set of interacting peers for practical deployment. This solution is actually implemented in [7]. Finally, the decisions made from the resource reciprocation policy are referred to as foresighted actions, as they enable peers to achieve maximum cumulative discounted rewards by considering the future rewards [4]. It is confirmed that the foresighted resource reciprocation strategy outperforms the regular BitTorrent protocol [4], [7].

While the foresighted resource reciprocation can improve the performance for file sharing, the reward function is defined as the received resources, and thus, the focus of the solution in [4] is only on maximizing the received resources. Hence, it can only provide a limited performance for multimedia streaming applications, as it does not consider multimedia characteristics especially timing constraints of multimedia data. This may result in undesirable interruptions of continuous playback of multimedia streams. In order to overcome this limitation, a modified reward function is proposed in [8], where each peer can explicitly consider the orderings of the data segments, while downloading them as fast as possible.

3. Foresighted Resource Reciprocation Strategy for Multimedia Streaming

In order to efficiently consider the characteristics of multimedia streaming, a priority function is incorporated into the original reward function, while explicitly considering the decoding deadlines (e.g., positions of data segments) and the quality impact. It modifies the reward function as a weighted sum of rewards in conjunction with the priority of packets. In [8], two types of priority functions are discussed, which are position depending priority function and segment-type depending priority function.

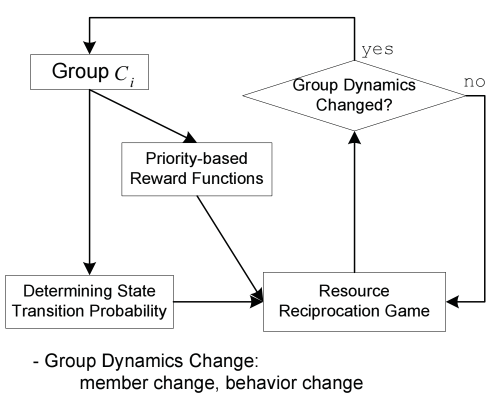

Figure 1. A block diagram of the foresighted resource reciprocation strategy for multimedia streaming

The position depending priority functions mainly focus on timing constraints in each data packet. Thus, the data segments can be prioritized based on their display time and peers can download more important data segments (i.e., the segments having higher priority) earlier. The position depending priority functions are illustrated as square shaped function and exponential shaped function, which represent differences between discrete and continuous priority functions. In addition, the segment-type depending priority functions focus on the type of compressed video packets such as I-, P-, and B-frames in MPEG or H.264 standards [9]. Thus, the corresponding data segments can also be characterized by the type of the frame they represent. A diagram for the foresighted resource reciprocation strategy for multimedia streaming is depicted in Figure 1.

The simulation results shown in [8] confirm that the approach outperforms several existing algorithms such as tit-for-tat in BitTorrent protocol and BiToS in P2P networks, in terms of packet loss rates and the video quality for given playback delays.

4. Conclusions and Future Research

In this article, we discussed a foresighted resource reciprocation algorithm and its variation such that this algorithm can efficiently support the multimedia streaming applications as well. In order to explicitly consider the timing constraints and different impacts of each data segment on the quality, several priority functions are studied and successfully incorporated into the foresighted resource reciprocation strategy. Results confirm that this approach outperforms several existing algorithms such as tit-for-tat and BiToS in P2P networks, in terms of packet loss rates and the video quality for given playback delays. Interesting future research topics may include the study of how to decide the system variables optimally in dynamic networks.

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