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Peer-assisted video streaming based on network coding and Beer-Quiche game

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ABSTRACT

This paper presents a novel peer-assisted video streaming based on game theory and network coding. Interactions between peers are modeled by a famous signaling game called Beer-Quiche. The Nash equilibrium analysis of the proposed game provides a reward and punishment mechanism which guarantees the free-riders failure and participation motivation. Due to using the game theory at design time, there is no additional complexity in the proposed method in contrast with many recent similar studies. Furthermore, it has avoided many inherent p2p system overheads such as frequent buffer mapping exchange between peers to obtain the necessary information about available chunks to other. The proposed scheme guarantees watching the video with minimum quality and eliminates the ability of peers to deny their own data. In order to create fairness, fine peers classification based on their action rating and request dispatch balancing are other achieved principles. The experimental results indicate that cooperative peers can receive 100% of base layer video chunks and get more than 99% of other high quality layers. Free-riders can not achieve more than 16% of video chunks even in the best case. Also, the sequel of low synergy is low received chunks in the proposed mechanism.

1. Introduction

In recent years, video has become the most important part of the Internet traffic. Also, forecasts suggest that the video traffic will grow in coming years. The increasing use of video applications and more demanding users to enhance the Quality-of-Experience (QoE) are the most significant reasons for this growth. Demands for watching High-Definition (HD) videos has had a significant growth from 2011, so that it will reach to more than 80% of video traffic by 2016 [1]. Also, new applications such as online interactive gaming with high frame rate (HFR) videos affect on the Internet traffic too [2]. ComeScore has stated in a report that the number of US users who watched on-line videos was more than 182 million in March 2013 [3]. According to this report, the number of videos which were watched was about 40 billion in the mentioned month. Cisco forecasts by 2019, about a million minutes of video will have crossed the network per second [4]. This document has expressed videos will consume 80 percents of all Internet traffic considering the fact that 70 percent of IP Video-on-Demand(VoD) traffic will be High Definition(HD) video in 2019. So, both recent reports and future forecasts prove that providing the bandwidth for this appli-

cation will be very challenging. Generally, there are two types of architecture for the Internet applications: client–server and peer-to-peer (p2p). Note, in contrast with client–server, p2p is more complex to manage while more scalable [5]. Indeed, p2p offers a seductive solution to the scalability problem of video streaming [6]. Despite scalability and some other benefits, p2p systems management is still a considerable research issue [7]. In order to exploit the benefits of both architectures, hybrid model has always been considered.

Video streaming over the Internet can be implemented by three ways: IP multicast, Content Distribution Network(CDN) and application layer multicast. In IP multicast, video source transmits a single stream while each router in the network distributes that stream to many receivers [8]. This approach was proposed by Deering for the first time [9]. Slow and costly deployment are the biggest limitations of this method. Content distribution or delivery networks (CDNs) is another solution for one-to-many streaming. Akamai [10] and Limelight [11] are some famous CDNs. Although this method is suitable for video streaming, it is not cost effective. Peer-to-peer is an application layer multicast method. In p2p, a logical overlay network is formed on top of physical topology. Each peer is a client and also a server. Despite the fact that, peer churn [12], free-riding [13], and the complexity of management are the problems of p2p, it is benefited from scalability and cost

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effectiveness. The combination of these approaches has been considered in recent investigations [14–16].

Video codec is another issue in the field of video streaming. Scalable video codec (SVC) is the most important approach in this scope. SVC can be scalable in three aspects: temporal, spacial, and quality [17]. In this layered structure, video is defined as a base layer and some other enhanced layers. Receiving the base layer is the minimum requirement to watch the video. If users want to improve their Quality-of-Experience, they must try to achieve other layers respectively.

This paper proposes a novel P2P video streaming approach which is modeled and analyzed by game theory. Indeed, the presented method is based on an extensive game with incomplete information which is called Beer-Quiche game. This game is placed in the field of signaling games [18]. The most important features of this method are summarized as follows:

- A peer-assisted structure which can be combined with CDN or cloud services for video streaming over the Internet.
- Designing a mechanism to avoid free-riding and motivating peers to be more cooperative based on Beer-Quiche game.
- Using the quality scalability of SVC for videos and also network coding. Each peer except free-riders, receives the base layer and some other data from video servers directly and tries to improve received video quality by interacting with other peers. Indeed, watching video with the minimum quality is guaranteed for all non free-rider peers.
- Avoiding additional data exchange overhead. Even in this system, peers are not forced to exchange their data (buffer) mapping with others. Note, data mapping which is an inevitable knowledge in a p2p system, indicates the peer's assets for future interactions.
- Fairness in peer classification based on their action rating. The proposed method takes into account that the status of classes are equal in the terms of peer participation.
- Request dispatch balancing. This means that all peers almost receive the equal number of requests from their neighbors.

Although many schemes have been proposed to address p2p video streaming challenges but this paper has some novel features as following in comparison with them: First, many proposed methods suffers from need to extra computation and communication overheads. The proposed method not only avoids from considerable additional computational and communicational overhead but it eliminates some inherent overhead in demand management of p2p video streaming. In fact, in a pull based p2p system, peers have to exchange buffer mapping together frequently to obtain the necessary information about available chunks to other. But the structure of overlay network in the proposed scheme resolves this need as well. Second, the proposed structure of this method constructs neighboring groups such a way that eliminates the possibility of dishonesty peers to declare their assets. This dishonesty is interpreted to peer cheating. Third, peers' resources are distributed fairly in neighboring groups in the scheme. Forth, requests are dispatched fairly among peers in the proposed mechanism. All of these features are discussed in the following.

The reminder of this paper is structured as follows: Background is presented in Section 2. Section 3 describes the proposed method. Simulation and its experimental results are considered in Section 4. Finally, the paper is concluded in Section 5.

2. Background

P2p video streaming applications can be categorized from different perspectives. In terms of overlay network structure, these applications can be mesh-based, tree-based [19,20] or the combination of these structures [21]. Tree-based overlays are divided into single tree and multi tree. Overcast [22] and ESM [23] are the first single tree based p2p video streaming applications. The lack of bandwidth efficient use in single trees motivates researchers to create multi trees [24,25]. Tree-based overlays can not perform well facing high peer churn [26]. In contrast, there is neither the single point of failure, nor the static topology in mesh-based structures. Each peer can establish and terminate peering relationship dynamically in a mesh-based overlay [27]. Although, the results of performed simulations in [28] show that mesh-based has more performance, but the invalidation of video flow leads to some challenges in comparison with tree-based [27]. Indeed, in tree-based overlays video flows from root to the nodes of the next levels of tree in a hierarchical structure but the flow is not detectable easily in mesh-based network. Hybrid approach such as Prime [29] and Chunkyspread [30] are benefited from both advantages of these structures.

Data transfer method or demands management is the other aspect of classification in this field. Generally, push-based, pull-based and hybrid model are obtained through this taxonomy. In push-based, upstream peer selects the receivers and pushes chunks to them, while downstream peer chooses one of the neighbors to send its request in a pull-based system [31]. Although, inherently, push is more fit to tree-based and pull is more appropriate for mesh-based, this is not a perpetual law. The hybrid of push and pull mechanisms leads to decreasing both delay and overhead, which are inherited from mesh, and also increasing the power of tree structure [32]. For example, both Coolstreaming and PPM use push–pull mechanism with hybrid and mesh overlay respectively [33].

In the point of application view, video streaming has two types: live video and video-on-demand(VoD). Tree or mesh or the combination of them can be used in the applications [34]. Anysee [35], Chainsaw [36] and PPLive [37] are the examples of mesh-based p2p live video streaming systems. Take BASS [38] and BiToS [39] as the mesh-based p2p VoD applications which use BitTorrent [40]. Finally, HyPO [41] and mTreebone [42] are the hybrid live p2p video streaming.

2.1. Game theory and mechanism design

Game theory is a mathematical tool to model and analyze conflict and cooperation between rational decision-makers [43]. When the focus is on the analysis games capability of this tool, the game theory is the proper phrase, and when a designing game with desirable outcome is considered, the purpose is mechanism design. In the other words, mechanism design is reverse engineering of games [44]. Although game theory implicitly includes the mechanism design issues in a more general sense. Interaction between existing entities in a system can be modeled as a game. Each entity is a player which can choose a proper strategy to maximize its payoff during the life cycle of the system. Note that payoff function for each player is not only dependent on its chosen strategy, but the actions of other players can also affect it. In p2p video streaming, all entities such as peers and video servers can be modeled as players in a game. They can choose an action during the video. It is important to mention that conflict in choosing strategies always exists in p2p video streaming. On one hand, sharing resources are costly for peers and video servers; on the other hand, sharing is inevitable to get success in the system. So, using game theory has been highly regarded in the recent investigations of p2p video streaming. Bandwidth allocation, create incentive and optimal scheduling are addressed in some p2p video streaming investigations by using game theory. Note that motivating peers to share their resources is an inherent traditional problem for all p2p