

IPTV Service Delivery over SP-driven P2P Networks - A Framework for Linear to Non-Linear Service Distribution

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Abstract—P2P-based IPTV service delivery is considered as the next killer application over the Internet. P2P systems address the issues of scalability and are considered most suitable architecture for the real-time content distribution/sharing. On the other hand, P2P applications show greedy behavior in the consumption of available network bandwidth and leads to the problems of inefficient utilization of network resources and poor interactions with other applications. These problems are due to the lack of coordination among service providers (SPs) and P2P applications. Thus, in this paper, we present a SP-driven P2P framework for the IPTV Service delivery to facilitate the service delivery mechanism with improved Quality of Services (QoS). The proposed mechanism is assisted by the explicit communications among SPs and P2P applications for efficient utilization of available resources. The proposed mechanism also addresses the issues related to QoS provisioning and the non-linear service distribution.

Index Terms— Media Streaming, P2P-based IPTV (Internet Protocol Television), QoS, SP-driven P2P networks, Non-linear service distribution.

I. INTRODUCTION

DURING the last few years, Internet has witnessed a massive growth in the deployment of real-time applications and multimedia services. We are living in a new phenomenon that has changed the way how users consume and interact with digital content over Internet. In fact, content sharing between communities has revolutionized the Internet due to the high popularity of Peer-to-Peer (P2P) networks. P2P architecture has gained tremendous attention during these years by facilitating the information flow from and back to the end users. Unlike traditional distributed systems based on pure client/server model, P2P networks are self organizing networks that aggregate large amount of heterogeneous computers called peers. Recent measurement studies [1] have shown that traffic generated by P2P applications has started to dominate the bandwidth consumption over Internet access links and P2P applications are utilizing around 70% of current available bandwidth over Internet. We expect even more growth in the future for the real-time content sharing rather downloading. This exponential growth is amplified by the wide adoption of handy and portable media capturing devices and the availability of high speed Internet connections up to the last mile.

P2P systems organize the participating peers in virtual overlay networks in order to support content/service delivery

effectively. The overlay networks are constructed virtually on the top of physical networks, in addition to the access and core networks and put significant advantages to the current Internet architecture. It provides a scalable solution in the content sharing/distribution to support increasing number of requests/users in more transparent way. Furthermore, it does not require many investments for deploying the infrastructure. Initially, P2P systems were designed for content distribution but nowadays P2P systems are widely used for many more applications due to its promising features. Today, the most popular applications based on P2P architecture include: video conferencing, signalling for IP telephony, P2P gaming, video streaming/video on demand, P2P-IPTV, etc. IPTV is expected to be the fast growing industry in coming years and according to some industry estimates there will be around 80 millions IPTV worldwide subscribers by 2011 [2].

The promising characteristics of P2P network make it more suitable for the deployment of the IPTV service. Nowadays, a number of service providers have adapted P2P mechanism to offer different services and Internet is undergoing through a massive shift from being a simple monolithic data service network to a ubiquitous multi-service. In the service delivery process, different stakeholders cooperate to offer value-added services to end-customer/content consumer (CCs). Content providers (CPs), service providers (SPs), and network providers (NPs) are the main stakeholders that have different roles, requirements and interests for providing such services. Regardless to the high popularity of P2P for wide adoption of service delivery it poses certain problems and eventually not acceptable for all the stakeholders participating in the service delivery process.

In this P2P-based service delivery process, network inefficiency is considered as one of the major problems caused by the P2P systems. P2P applications show greedy behavior and tend to utilize the maximum available bandwidth and other resources that ultimately affect the performance of other applications. This problem leads to extra network resource usage (e.g., using bandwidth of more links) and hence increase the network operational costs that is not acceptable for the NPs and SPs. On one hand, such inefficient utilization of bandwidth and inefficient interactions with other applications degrade the overall Quality-of-Service (QoS) for different applications. On the other hand, free riding is another problem with P2P system where many participating peers intend to join P2P network to utilize the available resources without sharing

their resources with others. P2P applications are popular and considered good to content owners, however from the network’s perspective, P2P is a problem. SPs guide applications to efficiently utilize the network resources but P2P applications implement their own policies and tend to utilize maximum available resources. Most of these problems arise due to lack of any central controlled entity that can manage P2P architecture by controlling the utilization of available resources. P2P users are determined to retrieve their desired media content more quickly although they do not have any knowledge on the underlying networking structure. SPs also have no control over the structure of the P2P networks and therefore they can neither control nor manage the associated traffic flows. These problems can be resolved by incorporating effective communication among network providers, service providers and P2Ps applications. Thus, in this paper, we present SP-driven P2P framework for the IPTV service delivery with the explicit communication among SPs and P2P applications. The main objective of this mechanism is to enhance the overall QoS for the IPTV service delivery while providing incentives and effective coordination among all the stakeholders. An abstract view of the SP-driven P2P network for the IPTV service delivery is present in Figure 1. The participating peers are organized in different overlay networks and this overlay network organization is assisted by the SP to allow users to consume contents in their personalized way. This SP-driven peers organization serves the requirements of all the heterogeneous client forming the P2P network. The content searching is performed in the distributed P2P fashion.

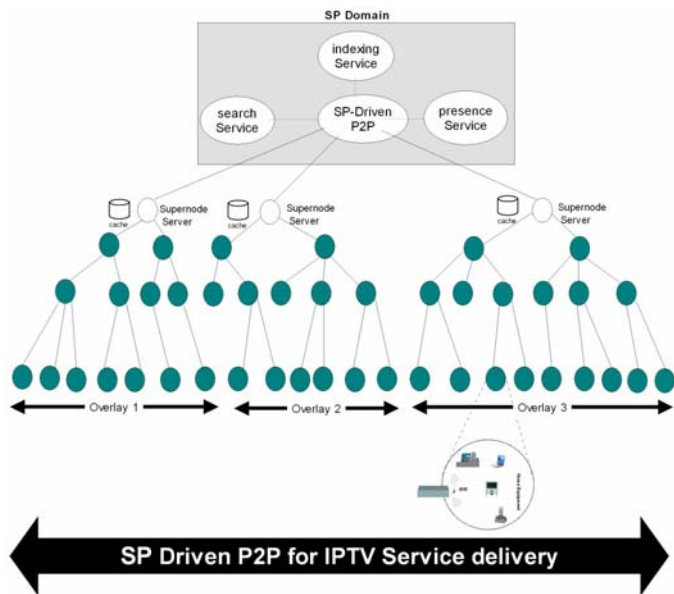


Figure 1. A big picture for SP-driven IPTV Service delivery

The rest of this paper is organized as follows: section-II briefly describes some of the related works for IPTV service delivery solutions along with the motivation for proposing SP-driven P2P mechanism, section-III describes the key components of SP-Driven P2P Network for IPTV Service Delivery. Section-IV illustrates the promising features

supported by our mechanism for the IPTV service delivery and finally section V concludes the paper along with highlighting some future perspectives.

II. RELATED WORKS AND MOTIVATION

The advances and popularity of P2P networks have drawn attentions of both academia and industry to propose solutions for the real-time streaming applications. P2P-based IPTV service delivery is hot area of study nowadays and a number of solutions are available for the subject. In this section, we briefly describe some of the existing work for IPTV service delivery along with our motivation to propose SP-driven P2P framework.

“CoolStreaming” is a framework known for P2PTV (peer-to-peer television) technology enabling users to share their television content with each other over the Internet. “CoolStreaming” is similar to that of the Bittorrent protocol, where participating peers upload their content at the same time as the programs are downloaded and viewed. “CoolStreaming” [3] framework is based on data-driven overlay networks where each node periodically exchanges data availability information with other nodes for the live media/video streaming. The participating nodes in the data-driven overlay network are organized using Breath-First-Search (BFS) tree structure, whereas the management of nodes that join the networks is controlled by an origin node. This origin node is persistent during the life time of the streaming session. This protocol implements an intelligent scheduling algorithm that copes well with the bandwidth differences of uploading clients and thus minimizes skipping during playback.

“PPLive” is the most popular mesh based framework for P2P-based IPTV services [4]. This protocol implements a P2P based video distribution protocol and the management of peers and channel discovery is supported by a gossip based protocol. A central server keeps track of all the available channels so, a new peer sends a query to central channel server to get the list of available channels while joining the network. PPLive maintains different buffer maps that provide the information for the availability of the requested video chunk with the respective peers. This mechanism enables the QoS measurement across the P2P networks and it provides the channels with data rate ranging from 250kbps to 450kbps, while few channels are available with 800kbps.

“GridMedia” is another well known system offering P2P-based IPTV services that has attracted more than 500,000 users all over the world with more than 15,000 concurrent users [5]. “GridMedia” organizes the peers in unstructured overlay networks and implements a push-pull based approach to fetch the media contents from the neighbor peers that exploit the benefits of the receiver-centric approach and also reduces the overall latency. “iGridMedia” [6] is an extension of the “GridMedia” protocol that is opensource and focus providing delay-guaranteed services to support real-time applications.

P4P [7] is a framework that provides an extension of the classical P2P framework to address the issues arising with the absence of any control over P2P. P4P framework provides a mechanism that allows effective control over network traffic

among network providers and certain applications. Such cooperation can be helpful in improving the QoS for application as well as for efficient service provision by the service providers. However, this framework is relatively young and no real mechanism has been proposed by the working group.

There exist a number of solutions for IPTV service delivery over the P2P networks. Although, P2P systems have addressed the issue of scalability and the available solutions have shown noticeable performance, however it leads to certain deficiencies that include inefficient utilization of network resources and inefficient interaction with other applications. Therefore, the motivation behind our SP-driven P2P framework is to provide a mechanism for IPTV service delivery that exploit the functionality of P2P networks while addressing the aforementioned problems. Furthermore, the proposed mechanism prevents the unauthorized peers accessing the available network resources. The detailed mechanism is presented in the following sections.

III. SP-DRIVEN P2P NETWORK FOR IPTV SERVICE DELIVERY

A. SP-driven P2P Network

In this section, we present our SP-Driven P2P mechanism for the efficient IPTV service delivery to cope with the shortcoming of classical P2P networks. SP-driven P2P mechanism intends to serve the large number of IPTV subscribers and ensure QoS provisioning till the last mile. Furthermore our proposed SP-driven P2P mechanism intends to provide efficient interaction among the P2P applications and service providers. This explicit interaction among both key-players put some control over the P2P architecture that results into additional revenues for SPs and additive QoS for the P2P applications.

The overall architecture of SP-driven P2P framework for IPTV service delivery is present in Figure 2. Service provider (SP) plays a vital role in this framework to support the service delivery. SP has to manage different entities to support the service delivery mechanism. SP has a global view of all the participating peers participating in this IPTV service delivery mechanism. The entities present with-in SP domain have their distinguished role in the overall service planning and efficient IPTV service delivery. Traffic forecast matrix provides a global view of available network resources. Network monitoring is performed to observe the network conditions and is further used for the resource provisioning. The SLS repository keeps information of all the service-level negotiations among different entities. The admission control mechanism is implemented to prevent unauthorized access of network by admitting or rejecting traffic flows over certain network links. SPs coordination block is responsible for the negotiations among different SPs through explicit communication for efficient utilization of shared resources.

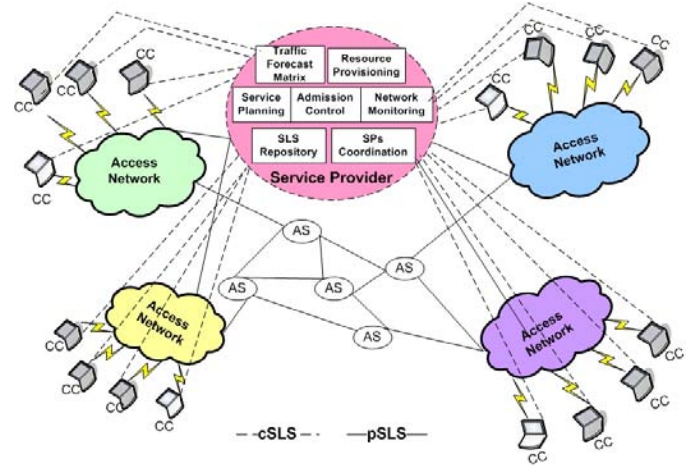


Figure 2. SP-driven P2P Network

Our SP-driven P2P mechanism allows better cooperation between P2P and service provider (SP) through explicit communications. SP updates and shares the current network conditions with P2P applications and allocates end-to-end network resources for efficient content delivery. SP organizes all the participating peers in virtual overlay networks. All the peers constituting P2P networks have multiple roles and may form coordinated groups/communities. The participating peers in overlay networks are organized on physical characteristics like media awareness (offered media content), locality-awareness (organization of peers having same characteristics closer to each other) and QoS-awareness (offered video quality). Initially, in SP-driven mechanism, we organize peers using the hybrid overlay organization that is composed of locality-awareness and context-awareness. All the peers offering same video quality are organized closer to each other and with respect to their virtual distances from receiver peer. Generally, overlay networks are intended to determine the routing over the service delivery path; however in our SP-driven P2P network such overlay organization is used to assist the receiver peer for choosing best sender peers. SP is responsible for the creation, maintenance, and destruction of these overlay networks. The overall mechanism is SP centric though the streaming mechanism for the IPTV service delivery is receiver centric, where each receiver peer selects multiple sender peers from the overlay networks. The overlay networks maintenance is essential in the dynamic behavior of P2P networks where peers enter and/or leave the networks more often and without any prior notification. In SP-driven P2P network, SP perform continuous network probing to maintain the overlay networks and thus to ensure the smooth content delivery.

In SP-driven P2P framework, traffic forecast matrix has a distinguished role beside other entities controlled by SP. This traffic forecast matrix is continuously updated for the current available and under utilized network links. The resource allocations are performed on the basis of requested TSPEC (traffic specification) by each receiver peers intending to receive IPTV services. For the resource provisioning SLA (service level agreements) and SLS (service level specifications) are negotiated between the NPs and SPs that

determine requirements for the service delivery. The traffic forecast matrix updates are also subject to these SLAs and SLSs negotiations. SPs administer a SuperNode tracker for updating the traffic forecast matrix and provide three kinds of services to the P2P applications including capability, policy and descriptor. Firstly, it specifies the capabilities of the network provider such as different classes of offered services. Secondly, it specifies how a network provider would like its network to be utilized by all the applications to avoid the inefficient interaction between P2P and non-P2P applications. Lastly, it specifies a descriptor for network status itself where it provides the autonomous system's (AS) id, the geographic peer location that is further used for overlay organization etc. We believe that such mechanism can address the issues of inefficient utilization of network resources and inefficient interaction among the applications. Moreover, such mechanism can be helpful to gain additional benefits for SPs and NPs due to some additional control and reduce the infrastructure costs. For the P2P applications perspective, SP-driven P2P framework enhances the overall QoS for the received services. This framework guides P2P applications to achieve more efficient network usage by avoiding expensive/congested network links to more desirable links that eventually ensure the smooth content delivery with the less start-up delay and latency.

B. Scalable Video Coding for IPTV Service Delivery

Video coding scheme is considered as a major driving force for the efficient IPTV service delivery with enhanced QoS. P2P networks are normally composed of heterogeneous clients interconnecting through heterogeneous access networks and have distinct requirement for the received media content. Thus, the selection of an appropriate video coding scheme is necessary for the IPTV service delivery. A number of video coding schemes are considered suitable for the real-time applications operating over heterogeneous networks and hence for IPTV services over P2P networks. Layered coding (LC) and multiple descriptions coding (MDC) are considered most suitable for many applications over heterogeneous and P2P networks. In both schemes original media content/video stream is truncated into further sub-streams called layers or description. Each layer/description can contribute to one or more characteristics of multimedia contents in terms of spatial, temporal resolution and quality (SNR level). LC and MDC transmit a suitable number of layers/descriptions to cope with the available bandwidth on the network paths. These both schemes have certain advantages and disadvantages for supporting real-time applications [8].

We consider the Scalable Video Coding as most appropriate video encoding scheme for the IPTV service delivery over the Sp-driven P2P networks. The scalable extension of H.264, known as Scalable Video Coding (SVC) is currently considered most promising video format for media streaming over heterogeneous networks [9][10]. A scalable video coding is capable to produce highly compressed bit-streams, in order to create a wide variety of bit-rates. In SVC coding scheme, each video stream is encoded in multiple video quality tiers. Each quality tier can be decodable with different characteristics. First tier which provides the basic quality of

the video is called "Base Tier" while other tiers, which are used to enhance the overall video quality of the base tier, are called "Enhancement Tiers".

Moreover, an original SVC stream can be truncated to produce video of different qualities, sizes, and frame rates, i.e. in SNR, spatial and temporal dimensions. This scalability makes SVC bit streams more suitable for heterogeneous networks and terminals for the streaming applications with improved QoS. In the SVC video coding, the base tier is encoded using a fully standard compatible H264 AVC, 7.5 frames per second in QCIF resolution. Then enhancement tiers can be added, each providing temporal, spatial, or SNR scalability. SVC provides the ability to decode the received content with different qualities depending on the reception of base video tier and lower enhancement tiers. Our SP-driven P2P framework assists the selection of base tier of video from the best available sender peer and the other video tiers accordingly their respective priorities. This SVC based coding has the ability to adapt to different heterogeneous networks and terminals where each service subscriber selects the video according to its user and terminal profile and preferences.

IV. LINEAR TO NON-LINEAR SERVICE DISTRIBUTION

IPTV is considered the next killer application over the Internet due to its promising features. It facilitates the consumers to have the opportunity to use interactive TV functionalities either in the real-time streaming mode or in video-on-demand (VoD) mode. Currently, interactivity is considered as an integral feature of IPTV services. In the SP-driven P2P framework, we intend to support the linear to non-linear IPTV service delivery along with the other interactive functionalities. Such non-linear service distribution deemed to be most fascinating feature of the IPTV service that allows users to use the service according to his preferences. The aim for the non-linear distribution is to allow the consumption of content shifts from a linear pre-packaged approach, to a personalized mode ("what the user wants, when he wants, on the terminal he wants"). In the non-linear distribution any user can access the pre-recorded content in VoD mode, either directly from the main content servers or with participating peers.

SP-driven P2P framework also ensures QoS provisioning by preventing the unauthorized peers from accessing the SP-driven P2P overlays. This QoS provisioning is performed by an admission control mechanism that is implemented to prevent unauthorized access of network by admitting or rejecting traffic flows over certain network links. This admission control mechanism resolves the issue of free riding in some extent. A brief summary of main phases for the IPTV service delivery is described in the Table 1.

TABLE 1. IPTV SERVICE DELIVERY OVER SP-DRIVEN P2P FRAMEWORK

Phase	Description
Bootstrapping	While joining the P2P network peers execute a bootstrapping function. In this phase new peers discover other on-line peers and connect them on the basis of set mechanism. No peer can participate in the content sharing process without this bootstrapping. In our mechanism, this bootstrapping process is assisted by the SP.
Searching	After the bootstrapping, peers search for the desired media contents. The searching is strongly influenced by the choice of neighbor peers resulting from bootstrapping step. This search process is facilitated by the SP that keeps tracks of the seeds (peers sharing their content) and leechers (peers also downloading content) in the P2P networks.
Resource Allocation	Receiver peer contacts the SP with a list of best sender peer with whom it aspires to start streaming. SP allocates the end-to-end aggregate pipes for the actual content delivery on the basis of available network resources. The resource allocation is influenced by the SLA and SLS among the SP and NP domains for the QoS provisioning.
Media Streaming	In this phase, actual streaming of audio/video content is performed. In SP-driven P2P framework, a single receiver selects multiple sender peers to receive media content. The selection of the multiple senders leads to the smooth content delivery but requires a careful scheduling among the sender peers.
Active Monitoring	Although the actual content delivery in the SP-driven framework is carried out using the designated QoS enabled pipes but it still requires active monitoring of the active network links to cope with any abrupt changes. We apply peer switching by selecting another best peer for the smooth content delivery
QoS Adaptation	QoS adaptation plays a vital role while assigning the different SVC video tiers to different sender peers. The received data throughput is compared against the

expected throughput from each sender peer to maintain an acceptable level of QoS throughout the streaming session. In this phase, we incorporate stream switching or video adaptation to maintain the smooth content delivery.

V. CONCLUSION & FUTURE PERSPECTIVE

In this paper, we presented a framework for the IPTV service delivery over SP-driven P2P networks. The proposed mechanism allows addressing the issues related to inefficient utilization of resources and providing mechanism for efficient interaction with other applications. The proposed mechanism enhances the overall QoS for the IPTV services with incorporation of effective QoS adaptation. The other promising features for our proposed mechanism include the linear to non-linear service distribution, QoS provisioning and proper authentication of the peers. In future, we aim to incorporate different parameters like the geographical information, coarse-grained distance metrics for the overlay networks organization to address the issues of heterogeneity. Furthermore, the efficient cooperation among different SPs domains needs to be addressed.

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