Open Issues in P2P Multimedia Streaming

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Abstract*— Peer to Peer networks (P2P) consist of a set of logically connected end-clients called peers, which form an application-level overlay network on top of the physical network. P2P solution facilitates contents/files sharing among Internet users in a fully distributed fashion. This paradigm is anticipated to resolve observed limitations in current centralized solution distribution and to significantly improve their performance. P2P networks are undergoing rapid progress and inspiring numerous developments. Although initially P2P networks were designed for file sharing, but their dynamic nature makes them challenging for media applications streaming. Despite recent advances in streaming P2P multimedia system, many research challenges remain to be tackled. This paper presents a state of the art study on several solutions, which exploit the power of P2P technique to improve the current multimedia streaming protocol. Different aspects related to the topic are explored in order to point out the open research issues in the domain of Peer to Peer Multimedia Streaming. Our foremost objective in this paper is to motivate and guide the ongoing research to tackle these challenging problems and help to realize efficient streaming multimedia P2P mechanisms.

Keywords: P2P, Video Streaming, Overlay Network architecure, Video Coding

I. INTRODUCTION

Within the next generation Internet, it is expected that the interest on multimedia services and in particular Video/Audio Streaming will grow up significantly. P2P traffic will take accordingly a non negligible amount of the global Internet exchange in the near future. Multimedia streaming over the Internet is mainly managed by Content Distribution Networks platforms (CDNs) such as Akamai [18], Limelight Networks [19] … Recall that a CDN platform is composed of a set of dedicated servers that are in charge of (1) content storing and (2) serving client demands by streaming and unicasting the requested content towards clients. Consequently, in order to achieve correct performance, CDNs must conduct an important infrastructure cost in order to avoid server bottleneck issues. Moreover, since multimedia streaming requires high bandwidth, server network bandwidth runs out rapidly using these architectures.

Another alternative may consist of using IP multicast systems for these applications. Indeed, IP Multicast is probably the most efficient solution; however its deployment remains limited due to many practical and political issues, such as the lack of incentives to install multicast-capable routers and to covey multicast traffic. Furthermore, the use of IP multicast is not adapted for some interesting cases (streaming from multiple senders for instance).

Concurrently, we observed the extreme popularity of P2P networks during last few years. They are autonomous and distributed systems that aggregate a large amount of heterogeneous nodes known as Peers. These peers incorporate with each other to accomplish some tasks/objectives. Such a system encompasses interesting characteristics like self configuration, self adaptation and self organization. P2P phenomenon offers several facilities. It allows information flow exchange from and back to end user, rapid and dynamic set up of communities sharing the same interests. The main targets of such systems are file sharing applications like Kazaa [15], eDonkey [16], BitTorrent [17]…

These intrinsic characteristics make the peer-to-peer (P2P) model a potential candidate to solve the pointed out problem in multimedia streaming over the Internet. P2P networks overcome the setback of bottleneck around centralized server due to its distributed design and architecture. Moreover, it facilitates to manage dynamically the available resources in the networks since they scale with the number of peers in the systems.

Although, P2P technology gives novel opportunities to define an efficient multimedia streaming application but at the same time, it brings a set of technical challenges and issues due to its dynamic and heterogeneous nature. Even though the problem has been already studied in the literature [11,12,13,14], works on P2P media streaming systems is still in the early stages, and for a P2P streaming to be enhanced, important research efforts and investigations are still required. Existing P2P protocols must be revised or re-invented and other specific problem need to be addressed to meet the multimedia streaming requirement.

Our objective in this article is two fold, firstly to provide a better understanding of the basic concepts of multimedia streaming over P2P networks, and secondly to identify research challenges related to this area. The rest of this article is organized as follows: P2P streaming network architecture is described in section II, a comparison for different video coding techniques in the context of P2P streaming is illustrated in section III, some existing solutions for the P2P media streaming are presented in section IV, we highlight certain issues for the domain in section V and paper is summed up by making some concluding remarks in section VI.

II. P2P NETWORK STREAMING ARCHITECTURE

The network streaming architecture refers to the manner used for multimedia content transfer and the entities which are involved during the streaming mechanism. In the context of P2P streaming, a given peer can play three different roles:

- Source: Peer containing the media contents and intended to share with other peers. Peer can store whole or a part of a given content
- Destination: It is the client who requests for the content. Client peer can obtained media contents from one or more sender peers depending on the architecture.
- Intermediate: An intermediate peer, receive a given content and then transmit it to the next intermediate peer. Intermediate peer serves as a transport node to facilitate the streaming mechanism.

The content media is distributed to the clients using generally an overlay network organized as an appropriate tree structure. The latter is rooted at the source or destination peer depending on the approach employed. Thus, we define two kinds of Network architectures

A. Multiple sources

Multiple source architecture is used when the multimedia contents are either replicated/existed within many source peers in the network, or it can be smartly split and dynamically placed within several peers.

Although the first case is more trivial since any content can be found in several emplacement into the network, especially if it is popular. In the second case a pre-processing phase and continuous analyses of client request is essential to place the different pieces of the content in the network to meet the client demands.

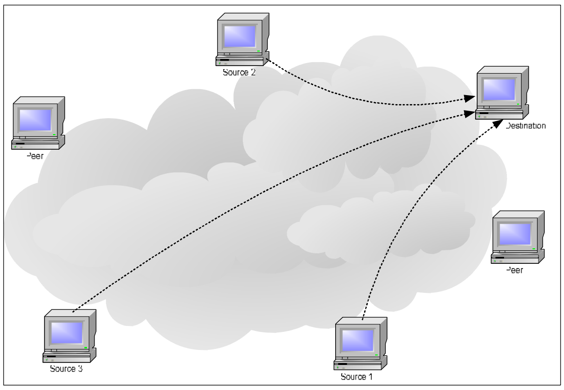

Figure 1. Multi-Source P2P streaming model

Therefore, as shown in Figure 1 contents can be retrieved from several peers into the network simultaneously. Here, each client peer receives packets of a multimedia content from multiple sender peers (peer having contents) while each sender peer can send packets to one or multiple client peers. The role of intermediate peer is limited to the transfer of the received packet towards the destination peer. Intermediate peers are not shown in the figure.

B. Single source

In this case, the multimedia content is stored into only one source peer in the network. The content peer starts transmitting the content to all client peers requesting for it. In this case, the intermediate nodes can play a more important role. To be significantly efficient, the intermediate nodes store some part of the content in their internal buffer. When a new client peer joins the network, it can directly retrieve the requested content from a given intermediate node. Hence, the overload around the source can be distributed over the entire network.

Figure 2 gives an example of single source streaming towards two peer clients.

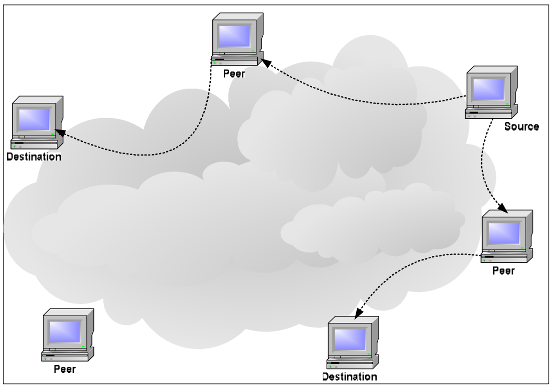

Figure 2. Single-Source P2P streaming model

In literature there exists other architecture for media streaming over P2P networks as well, like Central Server Based. CoopNet [11] solution is based on this central server model but here, we are concentrating on pure P2P architecture.

III. VIDEO CODING

In the following section, we explore video coding techniques used for video transportation over the IP network, and accordingly in P2P networks. Understanding of these techniques and related challenges to the choice of adequate techniques will help us to optimize the resource usage and to improve substantially the overall video quality.

Packet loss and error propagation that occur frequently over current IP networks can dramatically reduce the video quality at the receiver end. Hence, error resilience and handling packet loss are critical issues in the streaming applications. Several coding solutions have been developed to tackle these issues, to enhance the overall quality and to protect multimedia traffic against severe network conditions. There are mainly two major techniques for video encoding, Multiple description coding (MDC) and Layered Coding (LC) [4], which are analogous techniques

MDC and LC are useful in the case of varying bandwidth/throughput and losses/erasures due to congestion (as for Internet) and uncorrectable errors (as for wireless channels). Layered coding provides a scalable representation that enhances rate control but it is sensitive to transmission losses. On the other hand, multiple description coding provides increased resilience to packet losses by creating multiple streams that can be decoded independently.

In both these schemes, the multimedia stream is split into many descriptions/layers where each description/layer can contribute to the definition of one or more characteristics of multimedia data. The difference between MDC and LC lies in the dependency among description/layer. In the case of LC, layers are referred to as "base layer" and "enhancement layers". The base layer is one of the most important layers while the enhancement layers are referenced to the base layer. Enhancement layers can not be decodable independent to base layer. In contrast to Layered coding, in MDC each description can be decoded individually to get the base quality. However, with more descriptions being acquiring and decoded, the video distortion can be lowered and the larger is the output signal quality. MDC/LC eases the management of variable bandwidth/throughput by transmitting a suitable number of descriptions/layers.

MDC greatly improves loss/erasure resilience because each bitstream can be decoded independently, making it unlikely to have the same portion of data corrupted in every description. LC can improve error resilience when the protection level for a given layer can be adapted to its importance so that the base layer is more protected.

Other techniques have been proposed to enhance error/loss resilience of multimedia streams sent through unreliable channels. Among these, there are techniques like forward error detection/correction codes (FEC) or automatic repetition requests (ARQ). ARQ is very effective but it requires a feedback channel and it can be used only in point-to-point communications, not for broadcast. Of course, time must be allowed for retransmissions. On the opposite, FEC does not require a feedback channel and it is suitable for broadcast. Both these techniques, ARQ and/or FEC, can be used together with MDC/LC.

In the following section, we presented some related works that attempt to study the impact of video coding strategies on the streaming over P2P networks.

In [1], authors investigate streaming layered encoded video using peers. Each video is encoded into hierarchical layers which are stored on different peers. The system serves a client request by streaming multiple layers of the requested video from separate peers. The system provides an unequal error protection for different layers by varying the number of copies stored for each layer according to its importance. A comparison is made for the performance of layered coding with multiple description coding. The obtained results showed that layered coding is a better choice when the system can find and switch over to another server peer quickly, while MD-FEC performs better if the replacement time is non-negligible.

In [2], authors study the performance of multiple description coding and of layered coding for video streaming over the Internet. A comparison is conducted using different transmission schemes. Scenarios where transmission over multiple network paths is employed are also considered. The obtained results show that the relative performance of the two techniques varies substantially depending on the transmission scenario under consideration. It is seen that layered coding outperforms multiple description coding when rate-distortion optimized scheduling of the packet transmission is employed. The converse is observed for scenarios where the packet schedules are oblivious to the importance of the individual packets and their interdependencies.

In [3], authors examine both MDC and LC coding, distribution and substream placement in the network. For both schemes a traffic theory is developed. Authors formulate and solve the optimal solution of the problem of finding the optimal number of descriptions and their rates. The optimal number of sub-stream replicas for each video. A simple mechanism for placing the replicas in the server, for selecting servers, and for admission control is proposed as well.

For both MD and LC, the video quality improves as the peer "connect probability" increases. When the peer "connect probability" is small, the performance of the MD system is much better than the layered system. As peer connect probability increases, the performance of the layered system increases at a rate faster than the MD system. With zero replacement time, as the peer "connect probability" increases beyond a certain point, the layered system outperforms the MD system.

When the network is more reliable, LC is more efficient than MD. However, when the replacement time increases, the performance of the MD system is always better than the layered system. Therefore, the time to find a replacement peer has a bigger impact on the layered system than the MD system. The reason is that MD-FEC has inherent protection against sub-stream loss. When a single sub-stream is lost for MD-FEC, the video quality is only slightly affected. But for layered coding, all layers higher than this sub-stream cannot be decoded independent to the base layer at the receiver end.

IV. STREAMING OVER P2P NETWORK

In this section, we examine some works attempting to define efficient solutions for the multimedia streaming over P2P network. We presented the limitations for the proposed solutions as well.

Heffeda et al propse PROMISE [4]. The system realizes several optimizations so that the receiver will observe minimum fluctuation of media streaming quality. PROMISE encompasses the following functionalities (1) selecting the best sending peers, (2) monitoring the characteristics of the underlying network, (3) assigning streaming rates and data segments to the sending peers, and (4) dynamic switching of sending peers.

Three approaches are proposed for the selection of the best peers: (1) Random selection of peers that can fulfill the aggregate rate requirements. (2) E2E selection which estimates the “goodness” of the overlay path between each candidate peer and the receiver. (3) Topology aware selection which infers the underlying topology and its characteristics and considers the goodness of each segment of the path. Evaluation conducted formally and by simulation shows that the topology aware selection enable a judicious selection by avoiding peers whose paths are sharing a tight segment.

In [5] authors studied the construction of an efficient overlay P2P for multimedia streaming to handle network dynamicity and selfish user behavior.

The peer clients form overlays to forward the video streams over peer-to-peer. A given client, who joins the network, has to select a parent node that has sufficient bandwidth to itself. The selection mechanism of the parent node should allow admitting as many clients as possible in the long run. Assume that client sends a service request to the directory server and the directory server returns a list of candidates that can provide the service. The QoS parent selection algorithm uses the distance-bandwidth ratio as the metric in selecting the parent peer client.

ZIGZAG [6] deals with the problem of one source towards multiple destinations with consideration of network condition. The objectives are to minimize the E2E delay, to manage user dynamicity and to keep the overhead traffic as small as possible to achieve scalability

To realize this objective, ZIGZAG organizes receivers into a hierarchy of bounded-size clusters and builds the multicast tree based on that. The connectivity of this tree is enforced by a set of rules, which guarantees that the tree always has a height O($\log_k N$) and a node degree O(k^2), where N is the number of receivers and k a constant. The proposed approach helps in reducing the number of processing hops processing to avoid the network bottleneck.

In [8] DONet is presented, a Data-driven Overlay Network for live media streaming. The core operations in DONet are very simple and do not need any kind of complex tree structure for data transmission. Actually, every node periodically exchanges data availability information with a set of partners, and retrieves unavailable data from one or more partners, or supplies available data to partners. Authors show through analysis that DONet is scalable with bounded delay and also address a set of practical challenges for realizing DONet. An efficient member and Gossip based partnership management algorithm is proposed, together with an intelligent scheduling algorithm that achieves real-time and continuous distribution of streaming contents. Furthermore, mechanism for node failure and system recovery are also investigated

P2VoD [9] takes advantage of intermediate peers that forward the multimedia content by caching the most recent content of the video stream it receives. Existing clients in P2VoD can forward the video stream to a new client as long as they have enough out-bound bandwidth and still hold the first block of the video file in the buffer. A caching scheme is used to allow a group of clients, arriving to the system at different times, to store the same video content in the prefix of their buffers. An efficient control protocol to facilitate the manage join and failure recovery processes based on multicast tree is also proposed.

GnuStream [10] is built on the top of Gnutella. it is designed to takes into consideration the underlying P2P network dynamics and its heterogeneity. It handle bandwidth aggregation, adaptive buffer control, peer failure or degradation detection and streaming quality maintenance. The changes for peer status are detected using periodic probing. The Recovery from failure or degradation is handled by selecting the best peer.

CoopNet [11] is a solution for distributing streaming media content using cooperative networking. CoopNet solution is based on central server model. It provides resilience by introducing redundancy both in network paths via multiple, diverse distribution trees and in data using MDC. A centralized tree management protocol is used to construct short and diverse trees and support quick joins and leaves. Moreover, a scalable feedback mechanism is used to drive an adaptive MDC optimization algorithm. The tree efficiency is ensured by mapping between logical and physical topology.

Our proposed quality adaptive streaming mechanism [12] is based on the End-to-End “RTT” estimation among the receiver peer and sender peers. Active monitoring is performed to analyze the new network conditions and in peer switching is performed in the case of superfluous changes occurred on the network. To avoid the overhead we proposed End-to-End “RTT” estimation i.e. “RTT” among receiver and sender peers, for P2P streaming mechanism. We proposed to construct overlay networks for the sending peers based on the “RTT” and video quality offered by each peer. We used Object Classification Model for the MPEG-4 video by classifying the Audio and Video objects having certain priorities. Furthermore, layered coding is proposed for data encoding where original video is decomposed into different layers (Base Layers and Enhanced Layers) where Base Layer is most important.

In [13] A Hybrid Overlay Network protocol for on-demand media streaming is proposed. The overlays are maintained to ensure data transmission, called a "tree overlay" and a "gossip overlay". As named, the tree overlay is based on a tree structure rooted to the source. The gossip overlay is a random graph that uses random dissemination mechanism. Most data segments are delivered through the gossip overlay; only if a node fails to receive a data segment till certain deadline, will it resort to the tree overlay to fetch the segment from its parent. Compared to the tree structure, the random dissemination in gossip exploits the available bandwidth from all the potential network paths and also enhances robustness in the presence of bandwidth oscillations or malfunctions of internal tree nodes.

Anysee [14] is a peer-to-peer live streaming system tailored to fit cases where of multiple overlays is considered. Anysee adopts an inter-overlay optimization strategy by constructing and maintaining efficient paths using peers in different overlays.

Several optimizations are introduced: (1) the use of location mechanism for overlay construction to map underlay and overlay topology where constructing a given overlay network and its logical connection (2) the selection of an overlay manager by overlay network to manage peers join and leave. (3) On each node an Inter-overlay optimization manager is in charge to maintain one active path and backup path set. (4) Key node manager which enforce an adaptive admission control mechanism by introducing several queues. Actually received requests are transferred to the appropriate internal queue according to its priority. (5) Buffer manager which is responsible for receiving valid media data from multiple providers in the active streaming path set and continuously keeping the media playback.

Reza et al. have proposed the PALS framework [20] for P2P adaptive layered streaming. It is a receiver centric framework, where a receiver coordinates delivery of layer encoded stream from multiple senders. In this framework initial peers are selected on random basis because there is no information available in the start of streaming mechanism. After this initial stage, peer selection is performed by an iterative process. Each time a new peer is admitted and kept as sender peer only, if it enhances the overall throughput otherwise it is dropped. For the quality adaptation (QA), receiver manages its buffer regularly on the basis of packets consumption and sends the buffer state to each sender regularly. The QA mechanism for PALS determines inter-layer bandwidth allocation for a period of time rather than on a per-packet basis.

V. ISSUES IN MULTIMEDIA P2P STREAMING

The distinct features of P2P streaming systems bring many challenging issues. Despite the availability of many solutions, P2P streaming is still an active research area with many challenging problems to be addressed. We believe that an efficient solution must capture the following features:

A. Appropriate video coding scheme

The prone-error nature of multimedia content makes it highly sensible to the transmission over networks offering non-guaranteed transmission. Therefore, a reliable multimedia transmission system must involve a reliable video coding scheme. The use of an appropriate video coding scheme is more then essential, such a scheme must be sufficient flexible to meet the P2P network dynamics and its heterogeneity.

B. Managing Peer dynamicitiy

Since the peers (network nodes) are end-users terminal, their behaviour remains unpredictable. Due to dynamic nature of P2P networks, they are free to join and leave the service at any time without making any prior notification to other nodes. Thus, dynamicity management is crucial for the smooth play back rate during streaming session.

To prevent service interruption due to peer entrance\leaving, we need a robust and adaptive mechanism to manage such changes. The proposed mechanism must incorporate recovery phase gracefully to tackle the sudden changes occurred in the network. When a sender peer leaves the system, it must detect as early as possible and replaced with another sender peer to perform streaming in a smooth fashion.

C. Peer heterogeneity

Peers are heterogeneous in their capabilities. At network level, this heterogeneity may be caused either by different access networks connecting the peers, or by difference in the willingness of the peers to contribute. Each sender peers can have a different available bandwidth and that too might fluctuate after the connection is established. Peers Selection mechanism must be capable to tackle such heterogeneity problems as well.

D. Efficient overlay network Construction

The objective is to organize participating peers into a logical topology that must infer the underlying topology. In fact, a non suitable overlay topology can result in extra overhead and can reduce the system performance drastically. The overlay construction should be scalable.

E. Selection of the best peers

An efficient and flexible strategy must be introduced for the selection of sender peers and intermediate peer. In fact, another feature that must be captured in a streaming multimedia system is minimizing end to end delay performance metric where keeping the global overhead reasonable. In fact, the less this delay is, the more live the multimedia content is.

Since the multimedia content may have to go through a number of intermediate nodes, this will increase the E2E delay. The latter may also be long due to an occurrence of bottleneck at the source node. In both cases the routing protocol must select suitable strategy that enable the selection of the best peers minimizing the global E2E delay. Another important point is how to deal with underlay network optimization objectives while trying to satisfy P2P streaming overlay constraints.

Intelligent selections criteria need to be proposed to minimize the E2E delay by keeping in mind the number of intermediate node to be traversed and different routing policies.

On the other hand, for efficient use of network resources, the global control overhead introduced for network topology management should kept as small as possible. This is important to the scalability of a system with a large number of receivers.

F. Monitoring of network conditions

The network condition during streaming phase can be changed dramatically due to the dynamic nature of P2P architecture. So, along with the dynamicity management, it is important to monitor the current network conditions regularly. The available resources (bandwidth) can vary during streaming phase due to change in resource sharing by peers present in the network or due to arrival or removal of peers. The monitoring of current network conditions is necessary to maximize the utilization of available resources and to minimize the packet drop ratios at certain links.

G. Incentives for participating peers

In many studies, it is found that many peers join the P2P network to benefit from share other’s resources (more often data content) but they never share their own resources (bandwidth). It was reported that in 2000, 70% of Gnutella users shared no file but they only download contents [21]. In the presence of this issue, when no one is ready to share its bandwidth but wants to get share from other’s bandwidth, P2P network starts behaving like client-server architecture and it fails due to increasing number of client peers.

In future studies, we should tackle this issue as well. The issue can be resolve by offering some incentives to peers participating in streaming mechanism. The incentives can be incorporated using some economical modeling etc.

VI. CONCLUSION

Even we assist to a proliferation of P2P streaming solution over IP network; work in this area is still in the earlier stages.

In this paper, we have presented a comprehensive state of the art and related issues. Towards this end, we first exposed recent research work providing preliminary results related to the problems of P2P streaming over IP network. Moreover, we highlighted open challenges in the design of reliable solution that overcome the limitation of current approaches.

In our future works, we plan to investigate the above mentioned issues. Our major concern is to improve the overall received quality of multimedia streaming by leveraging the underlying network topology within the overlay P2P network and to model their interaction.

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