Comparison between Centralized & Decentralized Overlay Networks for Media Streaming

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ABSTRACT
In this paper we examine the performance of two types of Overlay networks i.e. Peer-to-Peer (P2P) & Content Delivery Network (CDN) media streaming using Multiple Description Coding (MDC). In both the approaches many servers simultaneously serve one requesting client with complementary descriptions. This approach improves reliability and decreases the data rate a server has to provide. We have implemented both approaches in the ns-2 network simulator. The experimental results indicate that the performance of Multiple Description Coding-based media streaming in case of P2P network is better than CDN.

Keywords: MDC, CDN, Video Streaming, P2P, Overlay Network

1. INTRODUCTION
We Media streaming received lot of attention in the past few years. As a consequence, live and on-demand media streaming is today widely used to stream TV & radio channels, TV shows, or arbitrary audio & video media. During this time several approaches have been devised to tackle the media-streaming problem. The first one is to use a client-server model, where a single server is the media provider and multiple clients are the media consumers. The second one is to use a peer-to-peer approach where the clients help the server in delivering the media content by having the roles of consumers and providers at the same time.

Both schemes have their advantages and disadvantages. The client-server approach has the advantage that the client receives the content directly from the server with the minimum delay but at the cost of overwhelming the server in particular situations (for instance at high rate hours: e.g. football / basketball games etc). As a result, the server's bandwidth can quickly become a bottleneck in the system due to the large number of client requests. On the other hand, in the peer-to-peer approach algorithms are devised to multicast the content between clients. In this case the clients have an active role in distributing the media content to other clients and thus remove the pressure from the server node. In this way, scaling the system functionality to a large number of consumers becomes a reality. However, this solution has its drawbacks too. Specifically, these algorithms have to tackle a high dynamic system, where clients can come and leave suddenly without any prior knowledge or guarantees.

Today's video streaming systems are mostly based on the client server model of Content Delivery Networks (CDN) which leads to several problems. The most important ones are:

1. Flash Crowd: Large numbers of streaming servers are not able to feed more than a few hundred streaming sessions simultaneously [14].
2. Bandwidth cost: It can be a significant problem to the content provider. In contrast, these costs are shared by every participant in the P2P streaming network.
3. Single Point of failure: Like any client-server model, the server is the single point of failure.

P2P networks offer characteristics and possibilities which cannot be provided by CDNs as proposed in [7]. As we show in this work, the performance of media streaming can he better in a P2P network, although the probability that one stream breaks is higher [10] [11]. The reason for this is that the replication rate of the video streams in a P2P network is typically significantly higher than in a CDN, due to the large number of participating hosts. In Gnutella for example, every peer shares an average of 500 files [6] and many peers host the same file.

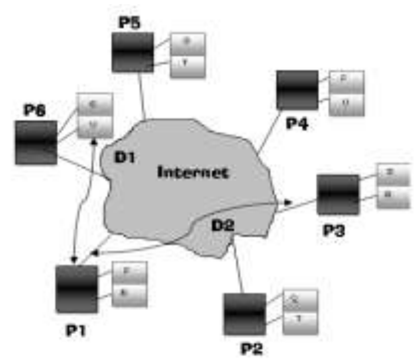

Figure 1: Distributed video streaming using multiple description coding in a P2P network. Peer P1 is simultaneously serve by the closest available peers P6 & P3 with descriptions D1 & D2 respectively.

Using MDC in a P2P streaming scenario is illustrated in Figure 1. Peer p1 wants to receive video file S which is available in the MDC format on p3, p5 and p6. In this example the video is encoded using two descriptions D1 & D2. Peers p3 and p6 are chosen based on the distance from server to the receiver, and they simultaneously serve the video file S, each one providing a complementary description. If both the descriptions are received at the receiving peer p1, it will experience the highest quality. If any of the descriptions are affected by packet loss or excessive delay, the receiver can still decode and display video S but at the expense of a degradation of the quality, as the descriptions are independently decodable.

2. MULTIPLE DESCRIPTION VIDEO CODING

Multiple Description coding (MDC) is a coding technique that fragments a single media stream into n sub streams ($n \geq 2$) referred to as descriptions. The packets of each description are routed over multiple, (partially) disjoint paths. In order to decode the media stream, any description can be used, however, the quality improves with the number of descriptions received in parallel. The idea of MDC is to provide error resilience to media streams. Since an arbitrary subset of descriptions can be used to decode the original stream, network congestion or packet losses which are common in best-effort networks such as the Internet will not interrupt the stream but only cause a (temporary) loss of quality. The quality of a stream can be expected to be roughly proportional to data rate sustained by the receiver.

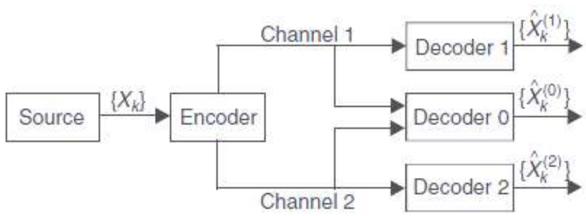

Figure 2: MD source coding with two channels and three receivers. The general case has M channels and 2^{M-1} receivers.

This property makes MDC highly suitable for lossy packet networks where there is no prioritization among the packets. The principle of MDC encoding/decoding is illustrated in figure 2. For a general overview on Multiple Description Coding (MDC) refer to [15].

3. VIDEO STREAMING OVER INTERNET

Media streaming systems are distinct from the file sharing systems [2], in which a client has to download the entire file before using it. Real-time multimedia, as the name implies, has timing constraints. For example, audio and video data must be played out continuously. If the data does not arrive in time, the play out process will pause, which is annoying to human ears and eyes. Real-time transport of live video or stored video is the predominant part of real-time multimedia. In this paper, we are concerned with video streaming, which refers to real-time transmission of stored video. There are two modes for transmission of stored video over the Internet, namely the download mode and the streaming mode (i.e., video streaming). In streaming mode, the video content need not be downloaded in full, but is being played out while parts of the content are being received and decoded. Due to its real-time nature, video streaming typically has bandwidth, delay and loss requirements. However, the current best-effort Internet does not offer any quality of service (QoS) guarantees to streaming video over the Internet. In addition, for multicast, it is difficult to efficiently support multicast video while providing service flexibility to meet a wide range of QoS requirements from the users. Thus, designing mechanisms and protocols for Internet streaming video poses many challenges. It has been demonstrated in [7] that using MDC in combination with packet path diversity significantly improves the robustness of a real-time video application.

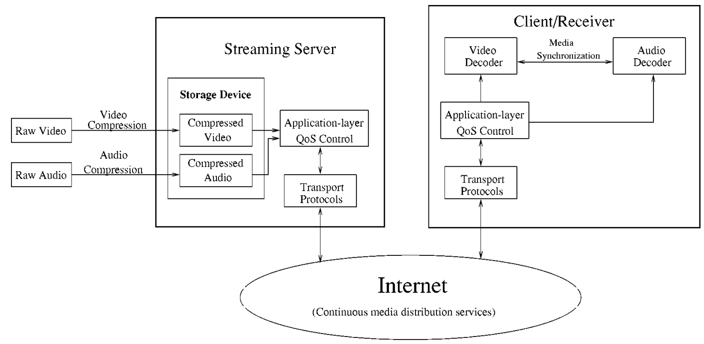

Figure 3: Architecture for video streaming.

In Figure 3, raw video and audio data are pre-compressed by video compression and audio compression algorithms and then saved in storage devices. Upon the client's request, a streaming server retrieves compressed video/audio data from storage devices and then the application-layer QoS control module adapts the video/audio bit-streams according to the network status and QoS requirements. After the adaptation, the transport protocols packetize the compressed bit-streams and send the video/audio packets to the Internet. Packets may be dropped or experience excessive delay inside the Internet due to congestion. To improve the quality of video/audio transmission, continuous media distribution services (e.g., caching) are deployed in the Internet. For packets that are successfully delivered to the receiver, they first pass through the transport layers and are then processed by the application layer before being decoded at the video/audio decoder. To achieve synchronization between video and audio presentations, media synchronization mechanisms are required. From Figure 3, it can be seen that the six areas are closely related and they are coherent constituents of the video streaming architecture.

4. MODELLING

We use the following methodologies in our simulations to reflect the real-world network situations.

4.1 Modeling Availability in P2P Networks

In P2P networks, peer and content availability poses a challenging problem to be solved. Availability of a peer in a P2P network is quite unpredictable, depending primarily on human presence. In our experiments we model peer availability as a 2 state markov process, having the states ON and OFF. The average lifetime of a peer in a Gnutella network is found to be about 30 minutes [3]. For our experiments we take a Gaussian distribution of ON time, which has a mean of 30 minutes. To model the availability of content among the peers, we randomly choose peers having a particular media file. We vary the percentage of peers having the file from 5% to 50%.

4.2 Server Placement in CDN

The server placement problem addresses how to optimally place a number of servers in order to maximize the quality at the end user. In our experiments we varied the number of servers to obtain measurement of Quality of Service, such as packet loss and response time. For a particular number of servers, we placed the servers randomly in the network and measured the average round trip-time from each user to the servers. We performed this random placement 10 times and chose the one yielding the smallest average round-trip-time.

4.3 Server Selection in P2P and CDN Network

The server selection problem addresses how to optimally choose a pair of servers to get complementary descriptions in order to maximize the perceived quality at the receiver. As described in [5] Apostolopoulos proposed a path diversity model which requires the knowledge of network topology, including knowledge of joint and disjoint links, and loss characteristics for each link. In our experiments we simply choose the closest two servers for each client request. For P2P case, we choose the closest two serving peers having the required content.

4.4 Content Distribution across Servers in CDN

This problem addresses how to optimally distribute the Multiple Description streams in an existing set of servers. In this paper we assume that all the CDN servers contain both the descriptions, which simplifies the server selection problem by merely choosing the two closest servers.

4.5 Network Load

To simulate the network load, we created random TCP connections originating from arbitrary nodes, on the average 3 new connections per second, each connection lasting for 1 minute.

5. RESULTS

We implemented both the P2P and CDN approaches within the Network Simulator ns-2 [13]. The topology was created using the GT-ITM topology generation tool with the transit-stub model, having 100 nodes. A video file of 1 minute duration, having a data-rate of 100 Kbit/s was selected for all the simulations. Each packet contains 1000 bytes. In both the CDN and P2P based systems, there is one new request every second, originating from an arbitrary node. In P2P network, the file is streamed from two closest available peer nodes with complementary descriptions, whereas in CDN, the same is served by two closest CDN servers. It was assumed that a peer can serve only one request at one time, while a CDN server can serve a maximum of 200 streams simultaneously.

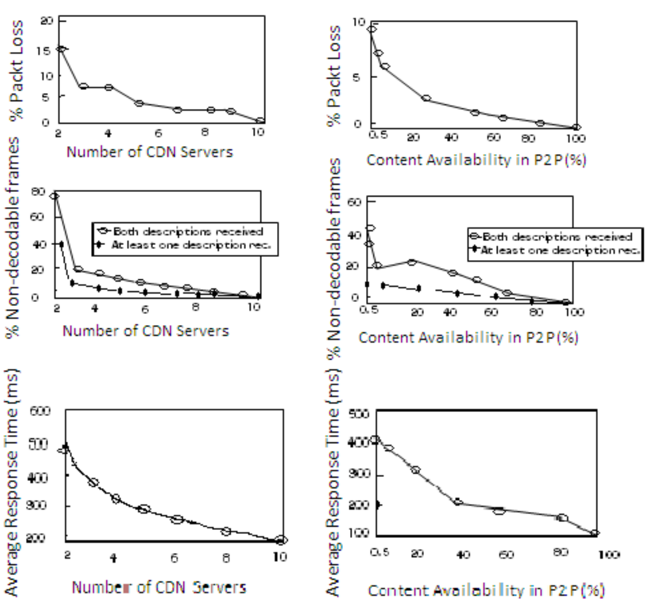

Figure 4: Performance of P2P and CDN networks using MDC: (top) packet loss rate varies with varying number of CDN servers and content availability in p2p network. (middle) number of decodable frames increases with increasing number of servers and availability. (bottom) average response times for P2P and CDN.

Figure 4 shows the results obtained through simulations. Three performance parameters, namely the rate of packet loss, number of non-decodable frames and the average response time, i.e. the time to receive the first video packet after the request has been sent, are compared for P2P and CDN networks. For the count of non decodable frames, it is assumed that the descriptions contain an Intra frame once in every second, and in case of a packet loss for the P-frames, all the subsequent frames become non-decodable, until the next I-frame is received. Because of MDC coding, the receiver can still view with a reduced frame rate, unless both the descriptions are corrupted simultaneously. This is shown in figure 5, where description s1 contains a packet loss, but s2 is received error-free. The receiver can view with ½ the original frame rate until the next I-frame is received in s1.

The simulation results indicate that the performance of a P2P network is comparable to that of a CDN, even at the high unavailability of peers and content in the p2p network.

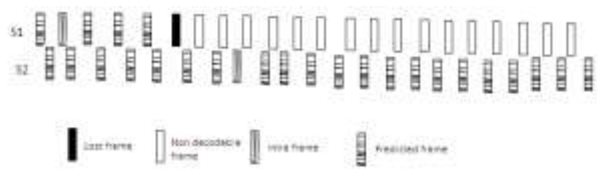

Figure 5: Impact of packet loss in MDC-based video streaming. Only stream s2 can be decoded completely. s1 is affected by packet loss and lead to locally reduced frame rate of the reconstructed video.

6. RELATED WORK

Peer-to-peer based media streaming approaches using multiple serving hosts have been proposed in [9] and [12]. In [7] MDC-based distributed video streaming has been proposed for content delivery networks. Our work is inspired by this work and we use the same multiple description encoding technique for a P2P network.

7. CONCLUSION

In this paper we presented a performance comparison of P2P media streaming with CDN – based media streaming, both employing MDC. The P2P approach takes advantage of multiple supplying peers to combat the inherent limitations of the P2P network and the best effort Internet. The media content is encoded using a multiple description encoder which allows realizing distributed streaming from more than one peer. In the final paper we plan to also provide experimental results on video dispersion, i.e. the time it takes to be able to satisfy a large number of streaming requests for a new video that is injected into the network, for both the P2P and CDN network.

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