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A Review on the Performance of Caching Algorithms for Video Streaming Services in IPTV

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***Abstract*— Due to the extensive adoption of broadband Internet services and recent progress in video technologies, Internet Protocol Television (IPTV) is becoming more and more important. IPTV offers a wide variety of interesting services such as VOD (Video on Demand), PVR (Personal Video Recorder), game, shopping as well as live TV broadcast. To sustain a variety of interactive services of IPTV, more complicated software should be equipped for video streaming services. In particular, the performance of video streaming services in IPTV environments is improved by the popularity-based interval caching. An IPTV system is appropriate to provide on-demand services because of its native return channel and its capability to easily deal with each user individually. On-demand services are becoming more popular in the present situation in which the users want to observe the offered content when and where it suits them best. As, multicast can no longer depend upon for such services, the traffic over certain parts of the IPTV network would increase drastically unless caches are implemented in strategic places within it. This paper focuses on the on demand services in IPTV. A thorough survey on various caching algorithms and other techniques which offers IPTV on demand services is presented in this paper.**

Keywords--- Internet Protocol Televisions (IPTV), Caching algorithms, Video on Demand (VoD),

I. INTRODUCTION

INTERNET Protocol Televisions (IPTVs) have become an active area of research in recent years due to the increased desire of TV consumers for interactivity and personalization. IPTV is a system which offers digital TV services through Internet protocol over the computer network infrastructure [1, 2]. With IPTV services, users can enjoy Video on Demand (VOD), TV shopping, online game, karaoke, Internet chat, E-magazine as well as live TV broadcast. Among the above said services, the most basic services offered by all IPTV service providers are live TV and VOD services. As live TV service is an option to terrestrial broadcast, cable TV, and satellite TV, VOD services provide movies which comprises of recent block-busters, a back catalog of films, and earlier broadcasted TV programs in an on-demand manner. Fig. 1 shows an overall architecture of the IPTV system including the two main IPTV services [3].

Live TV programs are encoded using an encoding server and then serviced to users with numerous interesting contents through a streaming server. Different from live TV programs, video contents such as movies and recorded TV programs are accumulated on a storage server and are serviced in an on-demand manner.

Users can view a list of titles and request to watch a specific title of video contents. The web server authorizes users or often makes up accounts, and the requested video contents are given to a particular user via streaming servers.

Ultimately, the delivered contents are given into the set-top box in the home, in which they are decoded and then displayed in multimedia applications. In recent times, with the advent of mobile IPTV technologies, IPTV contents can also be enjoyed with mobile terminals [4].

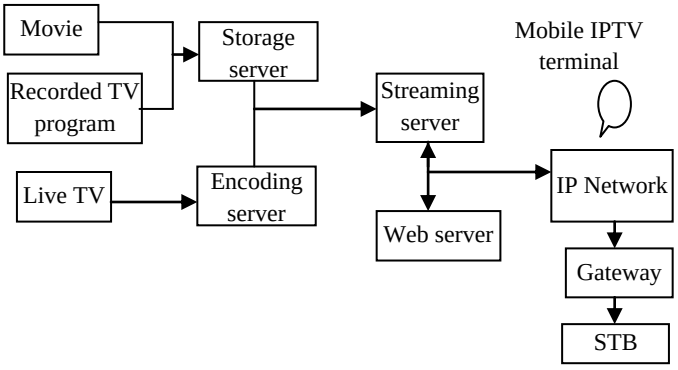

Figure 1: Overall Architecture of IPTV Networks

If most of the users are requesting video contents in a bursty way, storage servers consisting of video contents or streaming servers which are accountable for streaming the

requested video contents can be a blockage. In this scenario, certain users may feel the jitters when watching video contents. Although, there are no bursty requests for VOD services [5], the users may experience a little delay when starting to play the video contents. It is due to the reason that there exists an additional delay time in retrieving the requested contents from the storage server to the streaming server.

Caching of video contents can be a significant solution that lessens these problems of the users in IPTV's on-demand services [6, 7, 8]. Generally, as a segment of popular movies are mostly requested by several users, if certain popular video contents are cached, the load of storage servers can be lightened. Moreover, cached video contents can be immediately streamed to users without any start-up delay.

Due to the large volume of video data, however, contents level caching will not be effective. So, numerous approaches that cache data by a chunk unit called interval have been proposed by researchers [9]. But, most of the existing research techniques focused on fully exploiting the sequential access pattern of video data.

This paper provides the thorough investigations and analysis of the existing caching techniques in IPTV networks environments.

II. LITERATURE SURVEY

Kim et al., [10] presented a competent buffer management approach to support heterogeneous resolution display in home VOD services. This approach provides various quality services for a variety of home machines such as digital TV, home theater, and personal digital assistants (PDAs). In particular, this approach utilizes the reference popularity of video objects as well as the inter-arrival time between two consecutive requests on the same object. This approach also takes into account, various streaming rate of video objects to offer QoS adaptive VOD service for heterogeneous appliances. Experiments with real world VOD traces reveal this approach enhances the performance of home VOD systems significantly.

An IPTV set-top box offers a wide range of interesting services. In order to support numerous interactive services of IPTV, more sophisticated software should be equipped within the set-top box. Kim and H. Bahn [11] presented the implementation of a storage manager used in the IPTV set-top box. Similar to common purpose computer systems, software within the set-top box form a layered architecture which comprises of a collection of applications, an operating system, and device drivers. Each software component has its own functionalities and communicates with other components via well defined interfaces. But, the fixed interfaces often become an obstruction in providing certain vital information to other layers. For instance, media players with soft real-time necessities cannot provide the QoS information to the operating system efficiently as the POSIX interface is defined a long time ago. In order to handle problem, the author presented a novel technique that provides the QoS services by using only the file attributes without modifying the existing interfaces. The author implemented the prototype system Daphne on the Linux operating system. It is revealed from the experimental results that this approach is effective in guaranteeing the QoS.

Caching in a multimedia streaming server is playing a key role due to the occurrence of video-on-demand (VOD) services as well as the diffusion of several multimedia devices. But, due to certain abnormal characteristic features of multimedia objects and user activities in streaming services, design of a competent caching system becomes a more challenging issue compared to the conventional caching systems. Kim et al., [12] discussed certain vital problems that are of interest in the domain of multimedia streaming caching and proposed a novel cache management approach for multimedia streaming servers. This approach takes into account different streaming rates of multimedia objects as well as the inter-arrival time between two successive requests on an identical object. It also takes into account user activities in requesting and playing multimedia contents. Trace-driven simulations with real world VOD traces reveal that this approach considerably enhances the performance of multimedia streaming systems.

Presently, digital television is regularly replacing analogue TV. Even though, these digital TV services can be provided through several broadcast networks (e.g., terrestrial, cable, satellite), Internet Protocol TV over broadband telecommunication networks offers much more than conventional broadcast TV. It enhances the quality that users experience with this linear programming TV service and moreover it also paves the way for new TV services, such as video-on- demand, time-shifted TV, and network personal video recorder services, due to its integral return channel and the capability to address individual users. Degrande et al., [13] presented an overview of a typical IPTV network architecture and certain fundamental video coding concepts. Based on these fundamental concepts, the author then explained how IPTV can enhance the linear programming TV quality experienced by end users by minimizing channel-change latency and mitigating packet loss. For minimizing packet loss, forward error correction and automatic repeat request approaches are discussed, whereas for minimizing channel-change latency, a solution based on a circular buffer strategy is described. Additionally, this approach argues that the presence of larger buffers in the network facilitates IPTV to better offer new services (especially, time-shifted TV, network personal video recorder, and video-on-demand) than the competing platforms.

Video on Demand and other video services in an IPTV network construct large amount of unicast traffic from Video Hub Office (VHO) to subscribers and, thus, need further bandwidth and equipment resources in the network. In order to reduce this traffic and overall network cost, a segment of the video content may be stored in caches closer to subscribers, e.g., in a Digital Subscriber Line Access Multiplexer (DSLAM), a Central Office (CO), or in an Intermediate Office (IO). The problem is to reduce cost by

optimizing cache memory placement. Sofman et al., [14] proposed an analytical model of hierarchical cache optimization. This model is based on various fundamental parameters like traffic volume, cache hit rate as a function of memory size, topology (i.e. number of DSLAMs, service routers at CO, service switches at IO locations), and cost parameters. Certain realistic assumptions about a network cost structure and a hit rate function facilitates to attain an analytically optimal solution for the problem. It is demonstrated that an optimal cache architecture may utilizing caching at any combination of network hierarchy—DSLAM, CO and IO—depending on traffic, topology, and cost parameters. Thus, it is concluded that hierarchical caching is a vital option to consider for cost saving.

A WiMAX radio Resource Allocation (WRA) issue is studied in the framework of IPTV broadcasting over mobile WiMAX multicast, broadcast services (MBS) channels. The main aim is to enhance the quality of services, in terms of number of subscribers served; number of IPTV channels carried and perceived video qualities of individual viewers, subject to constraints on multicast channel capacities and space-time channel quality variations. Po-Han Wu and Yu Hen Hu [15] presented an effective heuristic technique depending on the Pareto principle that obtains near-optimal results in polynomial time complexity. The simulation results show that the performance of this approach is very significant when compared with other existing heuristic algorithms.

Automatic face indexing is a vital approach for understanding actor-based video services in an IPTV environment. Jae Young Choi et al., [16] proposed a novel face indexing model that takes benefits of the internet connection of an STB to generate a FR engine that is equipped with a high number of training face images. Moreover, the author used a face clustering approach to attain multiple face images of the same subject from a sequence of video frames. The clustered face images are integrated through a weighted feature fusion approach, resulting in a significant enhancement in face indexing accuracy. The efficiency of the proposed approach is evaluated through more than 300,000 video frames, grouped from five video clips containing drama or movie content. The experimental results reveal that the proposed approach can attain a face annotation accuracy that is feasible for practical applications.

The rising bandwidth in access networks, in integration with IPTV and Video on Demand (VoD) offerings, provides numerous chances to the users. The operators can no longer struggle exclusively on the number of channels or content and increasingly make high definition channels and Quality of Experience (QoE) a service differentiator. At the present scenario, conducting subjective experiments is the most trustworthy technique of evaluating and computing QoE, where human observers assess a series of short video sequences, thorugh one of the international standardized subjective quality assessment approaches. But, these experiments cannot be used for real life QoE evaluation of IPTV and VoD services as these subjective experiments require to be conducted in controlled environments and it may result in drawbacks on the sequences and overall experiment duration. Staelens et al., [17] presented a novel subjective quality evaluation technique based on full-length movies. This approach facilitates audiovisual quality evaluation in the same environments and under the same conditions users typically watch television. Using this new approach, the author conducted subjective experiments and compared the results with the existing standardized approach. It is observed that the significant differences in terms of impairment visibility and tolerance and highlight the importance of real-life QoE assessment.

The ITU-T and ISO/IEC standard for Scalable Video Coding (SVC) was recently finalized. SVC facilitates for scalability of the video bitstream in the temporal, spatial, or fidelity domain, or any integration of those domains. Video scalability may be used for several applications, such as saving bandwidth when the similar media content is needed to be sent concurrently on a broadcast medium at various resolutions to support heterogeneous devices, when unequal error protection shall be utilized for coverage extension both in wireless broadcasting and rate shaping in IPTV environments. Moreover, it may also be constructive in layered multicast transmission over the Internet or peer-to-peer networks or in any transmission case where prioritized transmission for network flows is significant. The application of SVC in the aforementioned scenarios is possible through standards for defining the transport format and process. Thus, a complete outline of the recently finished SVC standards on transport over IP/RTP and the MPEG-2 transport stream is presented by Schierl et al., [18]. Both standards are very essential for IPTV and video on demand, where the first is essential for SVC transport over mobile broadcast/multicast channels, and the latter is also vital for SVC transport over conventional digital broadcast channels.

Segment-based caching approaches have been investigated broadly for streaming media, because of the huge size of multimedia streams compared to traditional web objects. A survey on various segment based approaches such as prefix caching, segment caching, rate-split caching and sliding-interval caching is presented by Liu et al., [19]. The main purpose of prefix caching is to minimize the start-up delay by caching the initial segment of the stream at the proxy. This model is generalized by segment caching, where cache decisions are made for a series of segments of the stream. In rate-split caching, the partitioning is done along the rate axis, rather than along the time axis.

In this manner, the cache takes care of the peak rates in VBR streaming, while the backbone only has to cope with the lower constant rate. In Sliding-interval caching [20], the cached segment of the stream is primarily a growing prefix, but then, a dynamically updated sliding interval. This way, consecutive requests can be served from start to finish within this window.

A more advanced feature is the use of co-operative proxy caching [21], where a better performance than with

independent proxies can be achieved through load balancing and improved system scalability. In this case it is important to continuously keep track of cache states. Note that contrary to standard co-operative proxy caching, there is no need to switch to segments on other proxies when using co-operative proxy caching with sliding intervals. Similar peer-to-peer caching techniques have also been introduced in streaming CDNs, where whole files are stored instead of segments [22].

The rising fame of multimedia streaming applications invokes several problems in content distribution networks. Streaming services such as Video on Demand (VoD) or digital television over the Internet (IPTV) are very bandwidth-intensive and cannot endure the high delays and poor loss properties of the present Internet. In order to solve these issues, caching which is a sliding segment of popular streams at proxies could be predicted. Wauters et al., [23] presented a new caching approach and architecture for time-shifted television (tsTV) and its implementation using the IETF's real-time streaming protocol (RTSP). The technique utilizes sliding caching windows with sizes based on content popularity and/or distance metrics. The caches can be applied in both stand-alone mode and co-operative mode. It is shown that the network load can be significantly minimized through small diskless caches, particularly when using cooperative caching. The output of video content is likely to attain massive energy, fueled by the fame of user-generated clips, development of VoD libraries, and extensive exploitation of IPTV services with characteristic features such as CatchUp/Pause Live TV and NPVR abilities. The "time-shifted" nature of these personalized applications challenge the broadcast model underlying conventional TV networks, and increases the overall bandwidth demands by orders of magnitude. Caching approaches offer an efficient method for justifying these huge bandwidth needs by replicating the most famous content closer to the network edge, instead of storing it in a central site. The minimization in the traffic load reduces the needed transport capacity and capital expense, and lessens performance challenges. Borst et al., [24] proposed light-weight cooperative cache management techniques for increasing the traffic volume served from cache and reducing the bandwidth cost. As a canonical case, the author concentrated on a cluster of distributed caches, either associated directly or through a parent node, and formulated the content placement problem as a linear program to benchmark the globally optimal performance. Under some symmetry assumptions, the optimal solution of the linear program is observed to have a rather simple structure. The optimal structure provides important direction for the design of low-complexity cache management and replacement approaches. The author developed that the performance of this approach is assured to be within a constant factor from the globally optimal performance, with far more benign worst-case ratios than in previous work, even in asymmetric cases. The performance of the approach is evaluated using numerical experiments for typical popularity distributions. It is clearly observed from the results that performance of the proposed approach is significant and is better than the worst-case conditions indicated.

TECHNIQUES	FUNCTIONALITIES
[10]	Buffer management approach to support heterogeneous resolution display in home VOD services. The approach considers various streaming rate of video objects to offer QoS adaptive VOD service for heterogeneous appliances.
[11]	Implementation of a storage manager used in the IPTV set-top box. This technique provides the QoS services by using only the file attributes without modifying the existing interfaces.
[12]	This approach considers different streaming rates of multimedia objects as well as the inter-arrival time between two successive requests on an identical object.
[13]	Typical IPTV network architecture is presented which enhance the linear programming TV quality.
[14]	An analytical model of hierarchical cache optimization based on based on various fundamental parameters like traffic volume, cache hit rate as a function of memory size, topology etc.
[16]	novel face indexing model that takes benefits of the internet connection of an STB to generate a FR engine that is equipped with a high number of training face images
[17]	a novel subjective quality evaluation technique based on full-length movies
[19]	A survey on various segment based approaches such as prefix caching, segment caching, rate-split caching and sliding-interval caching
[23]	A caching approach and architecture for time-shifted television (tsTV) and its implementation using the IETF's real-time streaming protocol (RTSP)
[24]	A light-weight cooperative cache management techniques for increasing the traffic volume served from cache and reducing the bandwidth cost

Chen et al., [25] considered IPTV systems with a hierarchical architecture. The lowest elements of the architecture are Set-Top Boxes (STBs) at the user homes. A STB is associated to a Central Office (CO) which helps in delivering the video content to the end user. As, COs have

restricted storage abilities, they may require to recover a special video content that is requested by a user but temporary not stored in the local memory. Thus, COs exchange video contents with similar COs in a peer-to-peer fashion. At a higher hierarchical level, Video Source Offices (VSOs) provide the video contents that cannot be extracted at the CO level. Video content caching techniques at the COs and VSOs control the system performance through traffic exchanged between the network nodes. The author proposed two simple approaches that focus on minimizing both the intra and inter level traffic. The techniques are examined through an analytical model that is evaluated against simulation results. The results revealed that the hierarchical architecture facilitate good system performance even with inadequate overall storage capacity. The proposed approaches are very much useful in improving the performance of the system.

III. PROBLEMS AND DIRECTIONS

There are various problems and issues that are to be overcome in the existing techniques present in the IPTV environment.

Identifying an optimal (in terms of network cost) placement and amount of cache memory is a complex optimization problem [14].

Though most of the processors for IPTV set-tops using hardware-based built-in decoders exhibit good performance in processing high-resolution compressed video, they have drawbacks in running general purpose software as their embedded RISCs provide relatively low computing capability for minimized product costs [26]. Thus, the considerable software complexity that Rich Internet Application (RIA) runtimes need for graphics rendering and script processing cannot be correctly handled in such set-top environments.

Lack of standard APIs for IPTV systems is another cause for the complexity in adopting RIA. The RIA run-times for IPTV need specialized programming interface for media playback that can be characterized by IP-based media delivery and broadcast-oriented media format.

Moreover, most of the existing techniques mainly focused on bandwidth consumption. In fact, the main foundation for cooperative caching in distributed file systems is that bandwidth is assumed to be very large, and thus can be freely leveraged to enhance the response time performance. But, for high-definition video objects with sizes of a few GB's and hour-long durations, reducing the bandwidth usage is a more important objective than minimizing the initial play-out delay by a few hundred milliseconds.

The overcome the above mentioned problems, novel approaches are very much essential. Better and efficient optimization techniques and machine learning techniques have to be incorporated to arrive at a better technique which enhances the overall performance.

IV. CONCLUSION

An IPTV network in a metro area has a hierarchical structure. The main goal for IPTV network architecture is to bring QoS guaranteed video services to the end user at the lowest network cost (e.g., bandwidth) possible. Various caching algorithms for IPTV on demand video services are analyzed in this paper. In this article an overview of IPTV is briefly presented. The limitations of the existing works are analyzed and examined in this article. In order to handle the issues in the existing techniques, better caching algorithms have to be established. Better optimization and machine learning techniques have to be incorporated which would provide better results. This paper would help the researches to carry out various researches in the field of IPTV.

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