Optical Switching and Networking 18 (2015) 180–190

Contents lists available at ScienceDirect

Optical Switching and Networking

journal homepage: www.elsevier.com/locate/osn

IPTV over EPON: Synthetic traffic generation and performance evaluation

Partha Bhaumik [a,*], Abu Sayeem Reaz [a], Daisuke Murayama [b], Ken-Ichi Suzuki [b], Naoto Yoshimoto [b], Glen Kramer [c], Biswanath Mukherjee [a]

[a] Department of Computer Science, University of California, Davis, USA
[b] NTT Access Network Service Systems Laboratories, Kanagawa, Japan
[c] Broadcom Corporation, USA

A R T I C L E I N F O

Article history:
Received 13 June 2013
Received in revised form
29 April 2014
Accepted 6 May 2014
Available online 27 May 2014

Keywords:
IPTV
EPON
Video traffic modeling
Synthetic trace
IEEE 802.3av

A B S T R A C T

In an increasingly content-centric world where users consume large amounts of multimedia content, video delivery platforms over packet networks, such as Internet Protocol Television (IPTV), are gaining rapid popularity. At the same time, to serve the ever-increasing bandwidth demand from users, access networks, traditionally the bottleneck for high-bandwidth applications, are also undergoing rapid evolution. Forecasting how streaming IPTV over a network will perform is challenging as the data rate of a video stream varies with scene, time, framerate, and encoding. Nevertheless, it is important to evaluate the performance of an access network for IPTV traffic to ensure good Quality of Service (QoS) for users. Using video traces for such evaluation requires multiple video traces to represent different scenarios and generally involves slow I/O-based operations, such as file reading. To overcome these limitations, in this paper, we explore several aspects of modeling IPTV streaming, and present a synthetic video trace generator that closely resembles the empirical IPTV traces. Our analysis confirms that our synthetic video trace follows the statistical properties of empirical videos, and its resultant data rate is representative of the IPTV video streaming. Next we study the performance of Ethernet Passive Optical Network (EPON) in streaming IPTV by using the generated synthetic trace. Parameters of interest are the number of parallel video streams supported, the effects of the degree of video compression, average and maximum packet delays, and packet delay variances (jitter). It is shown that 10G-EPON can support a large number of parallel IPTV channels at moderate rates of video compression.

1. Introduction

Internet Protocol Television (IPTV) is a system through which television (TV) services such as live programs and Video on Demand (VoD) are delivered to end-users over a packet-switched network, such as the Internet, using the Internet Protocol (IP) suite. IPTV is a major application in the next-generation Internet and is expected to become ubiquitous in the near future. An end-user typically receives the IPTV services over an access network, so it is important to study the performance of access network technologies in streaming IPTV. Such a study can estimate important parameters such as the maximum number of parallel video channels, network properties (e.g., delay, jitter, and buffer size), required degree of video compression, etc. Several studies have previously analyzed the dominant characteristics of residential broadband traffic [1].

* Corresponding author.
E-mail addresses: pbhaumik@ucdavis.edu (P. Bhaumik), asreaz@ucdavis.edu (A. Sayeem Reaz), murayama.daisuke@lab.ntt.co.jp (D. Murayama), suzuki.kenichi@lab.ntt.co.jp (K.-I. Suzuki), yoshimoto.naoto@lab.ntt.co.jp (N. Yoshimoto), gkramer@broadcom.com (G. Kramer), bmukherjee@ucdavis.edu (B. Mukherjee).

http://dx.doi.org/10.1016/j.osn.2014.05.007
1573-4277/

However, an accurate traffic generator that focuses solely on IPTV traffic can be useful to operators. Although there are studies that evaluate the performance of IPTV after a field deployment [2], it is important to study these parameters before deploying the service in order to evaluate alternative network architectures or to configure the network for better performance.

Typically, IPTV represents a system of cable-like delivery services through broadcast or multicast channels over IP. Such service provides a set of channels to users, and each user selects a channel to view. However, there are several other video-distribution architectures that are often termed as IPTV such as Peer-to-Peer (P2P) video applications and WebTV/VoD where the server(s) hold(s) content, and users select specific content to view [3]. In our work, we focus on the broadcast channel service.

Popular encoding methods for streaming video include MPEG (Moving Picture Experts Group) and H.264 SVC (Scalable Video Coding) [4]. The encoding usually divides the periodic video frames into three major categories: I-frames, P-frames, and B-frames [5]. Fig. 1(a) shows a typical video compression pattern. The I-frame (Intra-coded frame) contains a complete image, like a conventional static image file. The P-frame (Predicted frame) carries the changes in the image from the previous I-frame or P-frame. The B-frame (Bi-predictive frame) uses differences between the current frame, and both the preceding and following frames. Thus, P-frames and B-frames contain only part of the image information, and hence, they provide video compression and lower the bit rate for streaming. The group of all frames from one I-frame until and excluding the next I-frame together is called a Group of Pictures (GoP) as shown in Fig. 1(a). GoP specifies the arrangement of I-frames, B-frames, and P-frames.

To match today's demands, IPTV service needs to be High Definition (HD), bandwidth efficient (to accommodate the delivery of HD quality video over an access network), and adaptive to network conditions. H.264 SVC can inherently deliver these properties as the average bit rate of an H.264 SVC encoding is typically half of the average bit rate of the corresponding MPEG-4 Part 2 encoding for the same video quality [6]. These favorable properties render H.264 SVC to be a strong candidate for the encoding of IPTV services.

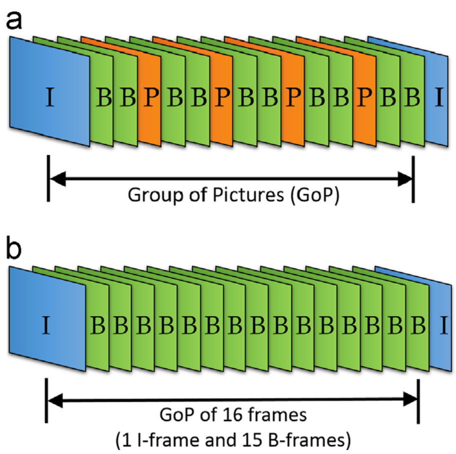

Fig. 1. Video compression patterns. (a) Frames in a typical video stream and (b) frames in a single-layer H.264 SVC coded video at highest compression.

A streaming HD video using H.264 SVC single-layer coding can be constructed with a number of I-frames, P-frames, and B-frames [4,7] in a GoP. For H.264 SVC, the highest compression can be achieved through the video compression that has 16 frames in a GoP with one I-frame and 15 B-frames without any P-frame, as shown in Fig. 1(b). This video compression is recommended for H.264 SVC [4]. A real trace for such a video with its statistical and compression properties can be found in [8].

Synthetic video trace generation requires a proper model that closely represents an empirical video. Our work focuses on modeling the IPTV because, once we obtain such a model, it can be easily distributed, used for performance evaluation, and the results can be reproduced anywhere. The ability to easily plug this generator into an access network evaluation platform is very attractive, as the performance of an access network can be evaluated for the benefit of operators.

Passive Optical Network (PON) is an attractive solution for the last-mile/first-mile problem in access networks. A PON does not employ any active elements in the signal path from source to destination, with only passive splitters and combiners being used. Advantages offered by PON over other subscriber access network technologies are large coverage area, lesser cost of maintenance (due to absence of active elements), and ease of upgrade to higher line rates and capacities. Ethernet PON (EPON) has been standardized in the IEEE 802.3ah (1G-EPON) and IEEE 802.3av (10G-EPON) standards, and has been widely deployed as the most prevalent PON technology. The advantages offered by EPON make it the access network of choice for bandwidth-intensive applications of the future Internet, such as IPTV and high-definition interactive gaming. Upcoming standards such as EPON Protocol over Coax [9] leverage the advantages of the EPON protocol to enable development of cost-effective high-speed next-generation access networks.

In this paper, we use our synthetic IPTV traffic generator to evaluate streaming performance in a standard 1G/10G-EPON. Parameters of interest are the maximum number of parallel IPTV sessions supported and the degree of compression required for good network performance.

The rest of the paper is organized as follows. Section 2 describes possible approaches that can be adopted for modeling IPTV traffic. Section 3 studies the distributions of scene lengths and frame sizes. Section 4 details the synthetic trace generation algorithm while Section 5 gives an analysis of the algorithm.[1] Section 6 explains our evaluation scenario and Section 7 gives the results and their interpretation.[2] Finally, Section 8 concludes the paper.

2. Modeling IPTV services

The modeling of IPTV services to evaluate the performance of an access network is a two-step process:

[1] Sections 2–5 were presented earlier in the first part of this study [10], and are reproduced here in greater detail.

[2] Sections 6 and 7 were presented in the second part of our study [11], and are being extended here with more detailed results.