Dimensioning of IPTV VoD Service in Heterogeneous Broadband Access Networks

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Abstract. The IPTV subscription rate has increased steadily since the introduction of IPTV Video on Demand (VoD) services. We have developed a model to determine the optimum deployment strategy for IPTV delivery network from the IPTV service providers' perspective. The analysis technique in this paper helps us determine the best deployment scenarios to support a certain number of customers within the tolerant boundary of Quality of Experience (QoE) measures. We define important QoE measures. The QoE will help service providers make deployment decisions including the number of servers, distance of servers from a community, and desirable access network bandwidth capacity.

Keywords: IPTV, VoD, QoE, IPTV network dimensioning.

1 Introduction

ITUT defines IPTV as multimedia streaming over IP networks with reasonable quality assurance [10]. Some IPTV service providers own full networking infrastructure such as AT&T and Verizon. Others need not necessarily own the full infrastructure such as AOL, Apple and Google; they might lease some part of the infrastructure or rely on the current Internet. Software product such as Microsoft Mediaroom [11] is used as the IPTV service provisioning platform by these telcos to provide IPTV services. IPTV video services can be broadly classified as live TV and video on demand (VoD). In future, a significant fraction of the IPTV traffic, up to 90%, may be due to VoD services [6]; and VoD services are resource intensive. However, the planning and deployment of VoD services in access networks (AN) has not been thoroughly studied. Mathematical models for IPTV network deployment [1, 4] have been proposed; however, they do not consider the heterogeneous aspect of network and actual deployment strategies. Furthermore, there are studies concentrating only on some specific technology deployment such as Ethernet based WDM networks with ring topology [2], Ethernet over SONET, and Ethernet over Fiber technology [3]. The network cost models for VoD services [4] have focused on video distribution strategies for reducing network cost based on hit ratio and cache size. The benefits of a P2P delivery mechanism for IPTV VoD servers have been explored [5], however they proposed bandwidth modeling only for P2P. In this study, we developed mathematical models to dimension IPTV network from a service provider perspective.

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IPTVs can have a complex network architecture as illustrated in Fig. 1 [3, 6]. A typical IPTV network is composed of super headend (SHE) and video hub offices (VHOs) at the national core. VHOs are connected to multiple video source servers (VSOs) which constitute the metropolitan area network (MAN) core, and VSOs are connected to central offices (COs) which are closer to the user communities. VSOs' edge routers route and aggregate local loop traffic from passive optical networks (PONs) ANs or from digital subscriber line access multiplexers (DSLAMs). There are video on demand (VoD) servers at each of these hierarchical levels. COs and VSOs are connected to the ANs. ANs can have multiple outside plants (OSP) connected to the CO. Each OSP may have a co-located DSLAM. These DSLAMs can be connected with the remote DSLAMs which will be directly connected with the end user communities. The IPTV infrastructure is logically divided into three main parts: client domain, network provider domain, and service provider domain [1]. IPTV service providers need to lease services from all these domains, for example, obtaining sustainable bandwidth within the client and network provider domains, and leasing optimum number of content servers. IPTV service providers provide the audio-video services to different kinds of users having different access network technology including fiber to home (FTTH), fiber to building (FTTB), xDSL or cable network. In such a heterogeneous environment, IPTV service providers need to consider heterogeneous network conditions while making optimum deployment strategy.

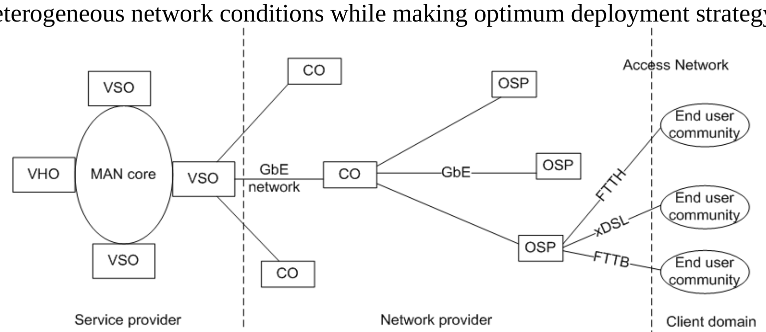

Fig. 1. IPTV network architecture.

This paper focuses on determining the optimum network deployment strategy for VoD services in a heterogeneous networking environment. We define essential QoE measures, and build an analysis model for each QoE. We can state our problem as follows: "Using user QoE & user requirements help service providers determine the number of servers, access network bandwidth requirements, and distance from server to users to fulfill IPTV VoD service in a heterogeneous access network".

2 Proposed Method

In this section, we explain our definition of community, the selected QoE metrics and overall design. A community is a group of IPTV subscribers sharing the similar characteristics, such as physical closeness, distance from the IPTV server, and the type of network access technology in use. A clustering-based algorithm can be implemented to delimit a community. Depending on the QoE measure, the community chooses the best servers for VoD data delivery. The community provides user viewing behavior, number of users in the community, mean link capacity, mean request rate during peak viewing hours, mean session duration, and mean distance from the community to the server. The network and server properties and their related metrics are driven from the network service and storage providers.

The network performance highly affects users' QoE for audio video services. Thus, while designing or dimensioning a network for video traffic, QoE is an important measure. ITU-T [10] divides QoE into two categories: subjective QoE and objective QoE. The subjective QoE includes emotions, linguistic background, attitude, and motivation. The objective QoE includes information loss and delay. Objective includes service factors, transport factors and application factors. In this paper when we refer to QoE we mean objective QoE. We utilize three objective QoE for this work, first is server's waiting time, second one way minimum delay and third is access network bandwidth consumption.

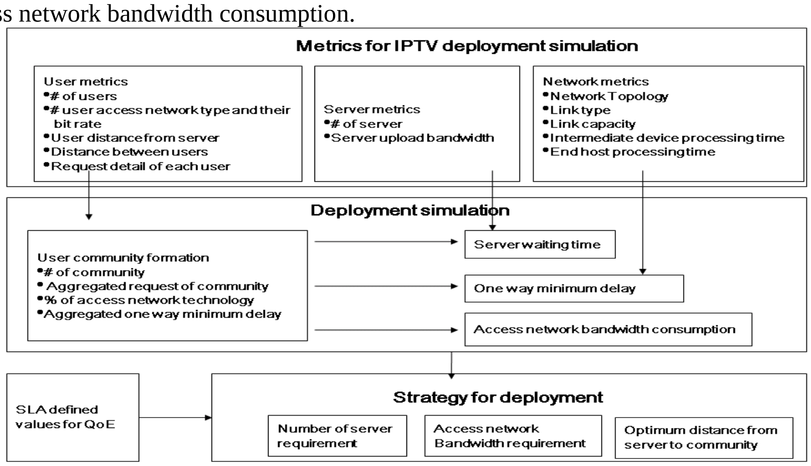

Fig. 2 Overall design showing interaction of input metrics with the models and optimization strategies for deployment

Server waiting delay is an important objective QoE measure. Communities generate service requests and servers fulfill these requests. As the load on a server increases the performance decreases; this causes delay in serving the requests. This QoE metric can help in determining whether IPTV service providers need to increase the number of server or upgrade the server capacity. The server is modeled using queuing theory [1]. The Erlang C [9] is most popular method to model server waiting time. One-way minimum delay in low traffic is an important QoE measure for VoD. One way is considered because we need to know only the time required to download VoD from server to community. Low traffic hours are considered, to avoid the effect of network congestion. This way we can determine the behavior of underlying network infrastructure. This is a deterministic delay, which is addition of the processing time of intermediate devices and end host, and propagation delay [8] of heterogeneous network. Heterogeneous network properties can be input to this model. The access network bandwidth consumption also affects user viewing quality; high bandwidth consumption causes an increase in latency and poor application performance at the end user. As we already discussed the AN can be heterogeneous. The download and upload bit rate of the network may vary depending on the different access technologies used [7]. While modeling the bandwidth consumption these parameters should be considered.

The inputs from the community, network providers and service providers are passed to the analysis models, which calculate three QoE measures, and help in analyzing the best deployment strategies (Fig 2.). All the QoE simulation models are independent of each other. The desired QoE values are provided in Service Level Agreement (SLA) from the IPTV service provider to the subscriber. For example SLA can define server waiting probability < 0.5 s, bandwidth occupancy < 0.5 and one way delay < 0.005 s. Service providers should meet minimum QoE conditions, and upgrade their networks whenever the QoE is not satisfied.

3 Conclusion and Future Work

The proposed modeling technique allows us to determine the optimum deployment conditions for a given number of potential IPTV VoD users while satisfying the pre-defined QoE measures. By analyzing user requirements and network configurations, we calculated substantial objective QoE such as server waiting time, one way minimum delay, and access network bandwidth consumption. The expected QoE conditions are compared, and used to guide deployment decisions considering the following parameters: the number of VoD servers, the physical distance of server from community, and AN bandwidth capacity. For future work, we will develop a more sophisticated model that considers content popularity and multiplexing aspects of network dimensioning. We will also explore various delivery mechanisms such as P2P, and multicasting for delivering VoD as well as live TV. We will develop models that consider various delivery mechanisms.

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