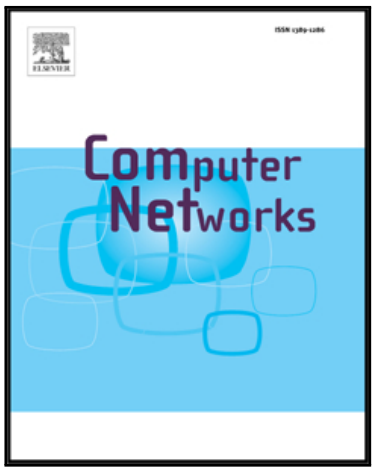

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Modeling the YouTube Stack: from Packets to Quality of Experience

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Abstract

YouTube is one of the most popular and volume-dominant services in today's Internet, and has changed the Web for ever. Consequently, network operators are forced to consider it in the design, deployment, and optimization of their networks. Taming YouTube requires a good understanding of the complete YouTube stack, from the network streaming service to the application itself. Understanding the interplays between individual YouTube functionalities and their implications for traffic and user Quality of Experience (QoE) becomes paramount nowadays. In this paper we characterize and model the YouTube stack at different layers, going from the generated network traffic to the QoE perceived by the users watching YouTube videos. Firstly, we present a network traffic model for the YouTube flow control mechanism, which permits to understand how YouTube provisions video traffic flows to users. Secondly, we investigate how traffic is consumed at the client side, deriving a simple model for the YouTube application. Thirdly, we analyze the implications for the end user, and present a model for the quality as perceived by them. This model is finally integrated into a system for real time QoE-based YouTube monitoring, highly useful to operators to assess the performance of their networks for provisioning YouTube videos. The central parameter for all the presented models is the buffer level at the YouTube application layer. This paper provides an extensive compendium of objective tools and models for network operators to better understand the YouTube traffic in their networks, to predict the playback behavior of the video player, and to assess how well they are doing in practice in delivering YouTube videos to their customers.

Keywords: YouTube, Progressive Streaming, Flow Control, Network Traffic Modeling, Quality of Experience Assessment, DASH.

1. Introduction

YouTube is one of the most popular services in today's Internet and is responsible for more than 20% of the overall Internet traffic [9], including mobile. Every minute, 100 hours of video material are uploaded and more than 1 billion unique users visit YouTube each month [10, 11]. YouTube's enormous popularity introduces severe challenges for network operators, who need to design their systems properly in order to cope with the high volume of traffic and the large number of users. Mobile operators are particularly sensitive to these challenges, as YouTube traffic is rapidly increasing in mobile networks, with more than 40% of all YouTube views coming from mobile devices today [10]. Since network operators need to offer satisfying video quality levels to prevent clients from churning, YouTube is an important application which has to be considered by operators, both in current highly competitive mobile and fixed broadband markets.

Consequently, Internet Service Providers (ISPs) do not only try to cope with a service like YouTube in the network. Instead, they actively include it in considerations of network optimization and operations. Thus, Quality of Service (QoS) provisioning is done in the network to meet requirements and provide guarantees, primarily, in order to ensure a good application quality. All these provisions strictly need a comprehensive understanding of the YouTube service in the network. More precisely, not only bandwidth requirements or minimum latency needs to be known, but also the impact of user interaction, the adaptation capabilities of the service, or possible implications for the users are required to be known. In short, for a specific consideration of YouTube in a network, one must understand YouTube at all its layers.

In this paper we present three models to explain the main features of YouTube in the network and for the user.

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