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journal homepage: www.elsevier.com/locate/compelecengVideo delivery networks: Challenges, solutions and future directions[☆]Qilin Fan^{a,*}, Hao Yin^a, Geyong Min^b, Po Yang^c, Yan Luo^d, Yongqiang Lyu^a, Haojun Huang^e, Libo Jiao^a^a Research Institute of Information Technology (RIIT), Tsinghua University, China^b Department of Mathematics and Computer Science, University of Exeter, England, United Kingdom^c Department of Computer Science, Liverpool John Moores University, England, United Kingdom^d Department of Electrical and Computer Engineering, University of Massachusetts Lowell, Massachusetts^e Department of Communication Engineering, Wuhan University, China

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ABSTRACT

Internet video ecosystems are faced with the increasing requirements in versatile applications, ubiquitous consumption and freedom of creation and sharing, in which the user experience for high-quality services has become more and more important. Internet is also under tremendous pressure due to the exponential growth in video consumption. Video providers have been using content delivery networks (CDNs) to deliver high-quality video services. However, the new features in video generation and consumption require CDN to address the scalability, quality of service and flexibility challenges. As a result, we need to rethink future CDN for sustainable video delivery. To this end, we give an overview for the Internet video ecosystem evolution. We survey the existing video delivery solutions from the perspective of economic relationships, algorithms, mechanisms and architectures. At the end of the article, we propose a data-driven information plane for video delivery network as the future direction and discuss two case studies to demonstrate its necessity.

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1. Introduction

Video is a kind of important media for communication and entertainment. In the past decade, the consumption of video contents changed from offline viewing to online streaming, which imposed stringent requirements on the network latency and throughput of video delivery network. Internet video ecosystem has experienced new characteristics accordingly: (1) the diversity of video applications, such as online streaming (e.g., IPTV and Netflix), and real-time video conferencing (e.g., Skype), (2) the ubiquitous video consumption by users who watch videos wherever they are and whenever they can; and (3) the freedom in the creating, distributing and sharing of user generated video contents through online video services such as YouTube, Vimeo or Hulu. The situation is further deteriorated by the emerging trends of adopting higher definition video streams, requesting more and more bandwidth. The Cisco predicts that video consumption will amount to 82% of the global consumer traffic in 2020 [1]. In conjunction with these growing traffic volumes, users' expectations of high quality of experience (e.g., high-definition video, low re-buffering, low startup delays) are continuously increasing [2].

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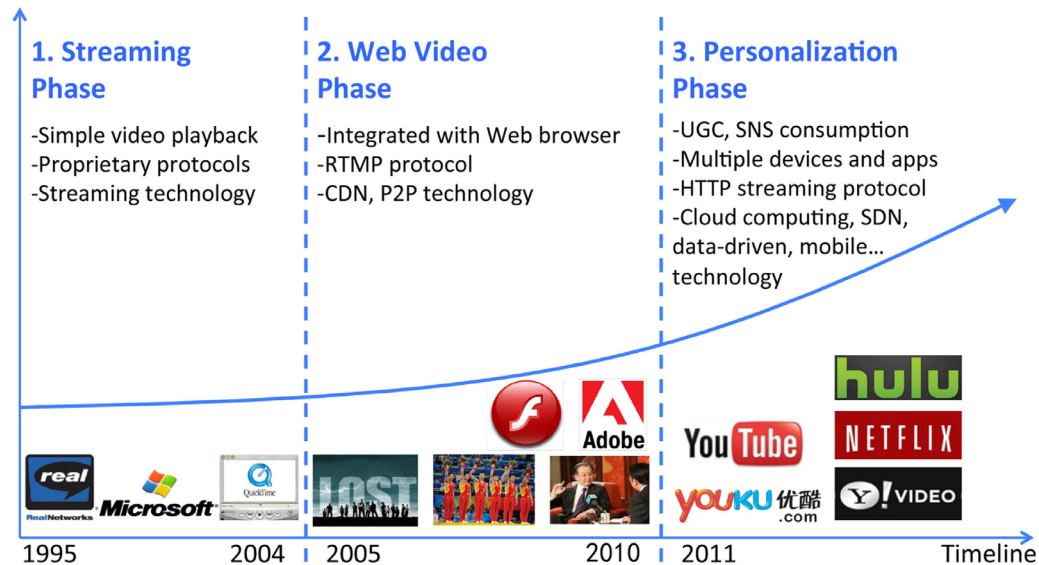


Fig. 1. Evolution of Internet video ecosystem.

Content Delivery Networks (CDNs) have been playing a critical role in content hosting, orchestration, mashup, transport, and edge access. Today, video providers rely on CDNs, such as Akamai and Limelight to serve video content across different geographical locations. However, with the new characteristics of Internet video generation and consumption, the architecture of today's HTTP-based CDN is being stressed [3].

As a result, there is a strong call for rethinking future evolution for sustainable video delivery. The state of the art in video delivery network has experienced a major boost in recent years, measured in the number of publications and industrial groups focused on the topic. Diverse interests have led to heterogeneous, fragmented landscapes. In this article, we give a comprehensive review and analysis on video delivery network, focusing on the major obstacles in the way of further progress and suggesting possible future direction.

The rest of the article is organized as follows. We firstly give an overview of both the evolution of Internet video ecosystem and the key challenges to video delivery network in new personalization phase. After a brief summary on the surveys in this field, we illustrate how existing approaches work to address parts of challenges from the perspective of economic relationships, algorithms, mechanisms and architectures. Finally, we suggest constructing data-driven multidimensional information plane for video delivery network as future research trend and conclude the article.

2. Video delivery network: evolution and challenges

Fig. 1 shows the evolution of video ecosystem experienced several important phases in the last two decades. In the mid-1990s, the Internet boosted from a text-based system to a multimedia-contained system. The representative streaming technique changed the way videos that are transmitted over the Internet, from the time-consuming downloads to real-time viewing. In 2005, Adobe system acquired the flash player which was originally developed by Macromedia, and flash soon became the de-facto standard for web-based streaming video (over RTMP) in this wave when videos explosively transmitted across the Internet along with widespread broadband access. Meanwhile, CDN and Peer-to-Peer (P2P) technologies emerged with the tide of the times.

Since 2011, the portable devices with cameras have become more and more ubiquitous, which enable users conveniently create and share videos. Users are increasingly demanding content on their terms - any content, any time, any device, any place. In addition, another key driver to the rapid explosion of streaming video was the technical shift from specialized streaming protocols such as RTMP to HTTP chunk-based streaming protocols. The use of commodity service greatly decreases the barrier of access entry by allowing video providers to utilize the existing HTTP-based CDN infrastructures in delivering videos to wide audiences. New applications, devices and protocols not only promote the Internet video ecosystem in the personalization phase, but also bring new challenges to the video delivery network. The key challenges can be summarized as follows.

- 1. High scalability:** We are witnessing a proliferation of videos over the Internet. For example, Netflix, a web service that streams premium video contents, accounted for 37% of peak download Internet traffic in North America in 2015. As of July 2015, more than 400 h of video were uploaded to YouTube every minute, up from 300 h min⁻¹ in November 2014. According to Cisco report [1], IP video traffic will be 82% of all consumer Internet traffic by 2020, up from 70% in 2015.

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