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Value networks and two-sided markets of Internet content delivery

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ABSTRACT

The volume and importance of content is increasing in the Internet, whereas the ability of the Internet architecture to scale to the growing demand for transport capacity is uncertain. Even though the natural growth in the demand continues, the growth in traffic volumes can be limited by reducing unnecessary content copying and redundant transportation of the same content. Information-centric networking (ICN), featuring globally unique naming of content and optimized in-network caching, has been suggested as a potential future solution to significantly reduce unnecessary traffic, but its economic feasibility has not been widely studied. This paper evaluates the economic feasibility of ICN by using the two-sided markets theory to analyze four Internet content delivery models: the client-server model, content delivery network (CDN) model, peer-to-peer model and ICN model. Value networks and two-sided markets of these content delivery models are identified in the process. The results suggest that content providers can be willing to pay for the lower delay of content delivery in ICN, if ICN can solve its coordination problems related to cost-allocation, contracting, quality of service guarantees, and content usage statistics. These incentive challenges are essentially the same as in-network web caching originally faced and could not overcome. Internet access providers may also consider investing in the deployment of ICN due to reduced interconnection costs. However, the ICN model may require a revenue-creating business model to make it more attractive to Internet access providers than the CDN model that provides similar cost savings.

1. Introduction

Fundamental changes are taking place in the Internet as the traffic and content volumes keep growing. By 2016, 86% of global consumer traffic is estimated to be video (Cisco, 2012) and a significant part of video content is cacheable by nature (e.g. Cha, Kwak, Rodriguez, Ahn, & Moon, 2007; Zink, Suh, Gu, & Kurose, 2009), which indicates that the importance of caching is increasing. A concrete example of the impact of caching comes from Uganda and Kenya, where the introduction of Google Global Cache increased users' Internet traffic volume by 300–1000% in only 2 weeks (Kende, 2012). Notably, content sources are consolidating and most Internet inter-domain traffic already today flows directly between large content providers (CPs), content delivery networks (CDNs) and consumer networks (Labovitz, Iekel-Johnson, McPherson, Oberheide, & Jahanian, 2010). As a consequence, the demand is shifting from plain (peer-to-peer) connectivity to value-added (video) content delivery services.

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The original end-to-end Internet architecture has not been able to solve the scalability and coordination problems of quality and caching in content delivery, which has led to the fragmentation of the Internet to overlay networks, such as CDNs (Clark et al., 2006). The growth of the CDN market is challenging the traditional transit and peering models, creating the need for a more uniform and efficient content delivery model better integrated to the Internet architecture. Information-centric networking (ICN), a new networking paradigm, utilizes in-network caching and adapts the network architecture to the content-driven network usage patterns (Ahlgren, Dannewitz, Imbrenda, Kutscher, & Ohlman, 2012). The concept introduces routing based on unique content names instead of content location (Dannewitz, 2009; Jacobson et al., 2012). In addition to the U.S. based Named Data Networking (NDN) project, two EU-funded research projects, SAIL and PURSUIT, have studied the concept. Even though the technical challenges are driving the research, the importance of the socio-economic aspects and stakeholder incentives should not be underestimated.

Studying the market dynamics of a technology just being defined is not simple. Our approach is to analyze similar technologies existing in the market and then draw conclusions based on the findings. In content delivery, CDNs utilize distributed caching closer to the end-user and focus on content instead of location, and thus can be considered as a precedent of ICN. In addition, peer-to-peer (P2P) networks distribute content all over the edge of the networks (i.e. in end-users' devices), which is also comparable to in-network caching of ICN.

Interestingly, a CDN can be considered as a two-sided platform, which aims at getting both CPs and Internet access providers (IAPs) on board with incentive-compatible cost allocation. Acting as a platform between CPs and IAPs (i.e. content consumers), CDNs have also been able to solve the coordination problems related to inter-domain quality of service (QoS). Due to the platform role and the network externalities existing in two-sided markets, CDNs have been a successful content delivery model (Faratin, 2007). Therefore, understanding how widely two-sided pricing is used in Internet content delivery is highly relevant in predicting the success of ICN.

In this paper, the feasibility of ICN is investigated based on the analysis of the following current and new Internet content delivery models: the client-server model, CDN model, P2P model and ICN model. Eight expert interviews covering key stakeholders (Internet service providers, CPs and data center providers) in Finland during 2010 (Zhang, 2010) are used as an input for identifying the value networks and two-sided markets of the content delivery models.

The rest of this paper is organized as follows. Section 2 gives a brief overview into the theories and background information underlying this work, such as the two-sided market theory and interconnection pricing. Section 3 describes the value networks of Internet content delivery models, so that the identification and analysis of two-sided markets is possible in Section 4. Section 5 presents a comparison of the different models and discusses the implications of the identified two-sided markets for the feasibility of ICN. Finally, Section 6 concludes the paper.

2. Background

To lay the basis for the analysis, the different Internet content delivery models are discussed in this section. In addition, two-sided pricing and interconnection pricing are presented briefly. Finally, the value network analysis theory and notations are described.

2.1. Internet content delivery models

This paper focuses on content delivery between CPs and consumers, and on content delivery models that the CPs can use. The client-server model, CDN model, P2P model and ICN model are alternative solutions for CPs to reach their audience and can exist in parallel. These models are briefly explained here.

2.1.1. Client-server model

In this paper, the client-server model means the basic end-to-end connection between the CP and the consumer. In the client-server model, the CP stores the content in a centralized server or pool of servers. The servers can be owned by the CP or leased as a service from data centers or cloud providers. The consumers, in this model, request content from these centralized servers based on the address of the servers.

Caching has been deployed in the client-server model in the form of web caches, which are designed to improve the experience of web browsing by lowering latency and reducing traffic volume in the Internet backbone and around the web servers (Huston, 1999). Web caching (Barish & Obraczka, 2000) can happen either on the client side, where visited web sites are cached in the client's device or in a close-by proxy server for a period of time, or on the server side, where for example search engines can cache search results. However, in this paper, web caching is excluded from the client-server model to differentiate it from the rest of the models.

2.1.2. Content delivery network model

The CDN model is an overlay to the basic Internet, which divides the end-to-end connection into two separate connections: one between the CP and the CDN provider, the other between the CDN provider and the consumer. The content is stored either permanently or temporarily at the CDN provider's servers, which are located closer to the end-users and, thus, reduce latency for end-users. However, Triukose, Wen, and Rabinovich (2011) suggest that CDNs may not yet have succeeded to fully exploit the delay cutting potential of decentralized edge caching. The other value added by a CDN is