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Multihoming, content delivery networks, and the market for Internet connectivity

Thorsten Hau [a,*], Dirk Burghardt [b], Walter Brenner [a]

[a] University of St. Gallen, Institute of Information Management, Müller-Friedberg-Strasse 8, CH-9000 St. Gallen, Switzerland
[b] University of St. Gallen, Department of Economics, Varnbüelstrasse 19, CH-9000 St. Gallen, Switzerland

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ABSTRACT

Peering points between different Internet service providers (ISPs) are among the bottlenecks of the Internet. Multihoming (MH) and content delivery networks (CDNs) are two technical solutions to bypass peering points and to improve the quality of data delivery. So far, however, there is no research that analyzes the economic effects of MH and CDNs on the market for Internet connectivity. This paper develops a static market model with locked-in end users and paid content. It shows that MH and CDNs create the possibility for terminating ISPs to engage in monopolistic pricing towards content providers, leading to a shift of rents from end users and content providers to ISPs. Implications for future innovations are discussed.

1. Introduction

Research on pricing of data transport has its roots in the literature on telecommunications. Early work on pricing of voice communications established the corner-stones of thinking about communications pricing. A prominent example for this is the focus on access charges (Laffont, Rey, & Tirole, 1998), that is, the price one provider pays to the other for the termination of traffic with an end user. The present paper departs from this "classical" view on communications pricing by also considering content providers (CPs), end users, and content delivery networks (CDNs) instead of only the inter carrier settlement. This issue is not covered in the existing literature. This paper shows how an Internet service provider (ISP) with access to end users can discriminate against CPs and charge monopoly prices for termination. The discussion is related to and uses results from research on one- and two-way access (Buehler & Schmutzler, 2006; Gans, 2006), strategic network pricing (Shrimali, 2008), two-sided markets (Armstrong, 2006; Rochet & Tirole, 2006), vertical integration (Rey & Tirole, 2007; Tirole, 1988), telecommunications pricing (Laffont, Marcus, Rey, & Tirole, 2003; MacKie-Mason & Varian, 1995; Shakkottai & Srikant, 2006), net neutrality (Crowcroft, 2007; Sidak, 2006; Wu, 2003) and quality of service (QoS) (Soldatos, Vayas, & Kormentzas, 2005; Wang, 2001).

The existing literature on telecommunications pricing has ignored the possibility that CPs and terminating ISPs directly interconnect. In contrast, consider the following two situations: First, it is commonplace that CPs buy transit directly from terminating ISPs, thus effectively paying them for preferential access to end users. This practice is called multihoming (MH) and plays a role in the exponential growth of routing tables (Bu, Gao, & Towsley, 2004). Second, CDNs are a popular way to enhance the flow of information on the Internet. A CDN uses local caches to keep distributed images of content close to end users without the need to traverse several ISPs'networks (Pathan & Buyya, 2007; Vakali & Pallis, 2003). Both

* Corresponding author.
E-mail addresses: thorsten.hau@swisscom.com (T. Hau), dirk.burghardt@unisg.ch (D. Burghardt), walter.brenner@unisg.ch (W. Brenner).

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technologies provide viable means to improve the speed and reliability of data transport from a CP's website to end users. This is due to the fact that peering points, that is, the points of interconnection between the networks of two ISPs are among the notorious bottlenecks of the Internet (Akella, Srinivasan, & Shaikh, 2003). Both technologies serve as ways to bypass these peerings and to gain more direct access to end users, thus increasing the probability of timely delivery of data to the end user.

The remainder of this paper is structured as follows: Section 2 explains the relevant entities of the Internet that are needed for a formal model. Section 3 presents a formalized treatment of six scenarios that shows how MH and CDNs affect ISPs'incentives to price traffic in comparison to the standard situation with peering. The model is static with locked-in end users who cannot switch their provider. In Section 4 the consequences of the model are discussed and a sketch of an agenda for further research is provided.

2. The market for Internet connectivity

Figs. 1 and 2 show in an idealized manner the structure of the Internet (Shakkottai & Srikant, 2006; Uludag et al., 2007). Fig. 1 focuses on the interconnection aspect. Several ISPs interconnect with each other through points of interconnection (denoted by "I"). Fig. 2 focuses on the hierarchical structure of the Internet. Data first flows up the hierarchy from a CP to its ISP and across a peering point back down via an ISP to the end user (EU).

A common approximation (Laffont et al., 2003) used is that CPs (web sites) only send traffic and end users (EUs) only receive traffic. This approximation is justified by the real traffic patterns on the Internet which show that downstream data transmission volume to end users is much bigger than that upstream. This assumption excludes peer to peer relationships from the analysis.

2.1. Internet service providers

ISPs provide connectivity to end users and CPs. They interconnect at peering points and the originating ISP pays an access fee a to the terminating ISP. In Fig. 2, ISP 3 would pay ISP 2 for delivering data from the content provider to the end user it is connected to. It is assumed that ISPs have no lack of bandwidth on their backbones and could provide quality assurance to traffic either through excess capacity or network management techniques. Managing capacity on the backbone is within the ISPs'power and there are no interdependencies with other ISPs. Further bandwidth bottlenecks may be present in the peering points and in the access network. Possible problems due to constrained access bandwidth are ignored and concentration is on the peering points.

2.2. Points of interconnection

In Figs. 1 and 2 the circles with an "I" represent points of interconnection or peering points where different ISPs interconnect their networks to form the Internet. There are two dominant modes of interconnection: Peering and transit. Peering (Shrimali & Kumar, 2008) is a settlement free agreement to exchange traffic while transit involves payments for exchanged data. Typically peering agreements are used between ISPs of similar size while transit charges are paid by small ISPs to larger ISPs.

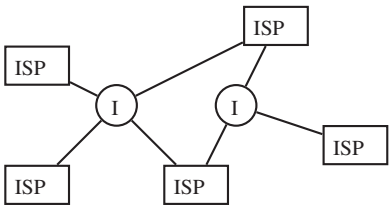

Fig. 1. Interconnection structure of the Internet.

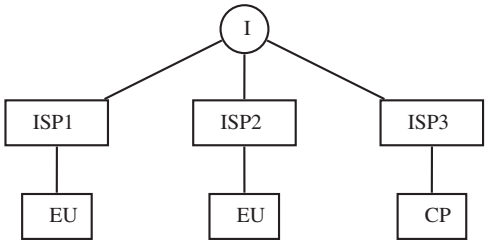

Fig. 2. Hierarchical structure of the Internet.