STATEMENT OF CRAIG LABOVITZ, PHD

Co-Founder and CEO of DeepField

Before the House Judiciary Committee Subcommittee on Regulatory Reform, Commercial and Antitrust Law

Hearing on "Competition in the Video and Broadband Market: the Proposed Merger of Comcast and Time Warner Cable"

May 8, 2014

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Mr. Chairman, Ranking Member Conyers, Chairman Bachus, Ranking Member Johnson, and Members of the Subcommittee,

I am pleased to be here today to discuss some of the technical issues relating to the current state and historical evolution of Internet interconnection that may be relevant to your consideration of the proposed Comcast-Time Warner Cable merger. At the outset, I want you to know that Comcast and Time Warner Cable are two of a substantial number of companies with which my company, DeepField, has commercial relationships. However, the views expressed in my testimony are my own.

I am both an academic researcher and commercial vendor. I have studied and published numerous papers on changes in Internet infrastructure and interconnection over the last 20 years. My current company, DeepField, provides network management and analytics solutions to a broad range of both large content companies and consumer Internet providers.

My research interest in Internet infrastructure dates back to the earliest days of the Internet. In the early 1990s, I began my career as a backbone engineer on the National Science Foundation (NSFNet) research precursor to today's Internet.[1] My NSFNet work covered a range of technical projects, including the design of the software that enabled the first commercial interconnections

to the Internet. Later, my professional and research responsibilities expanded to include roles as the chairman of the principal Internet industry engineering association in North America[2] and as the project director of several National Science Foundation funded research projects studying Internet infrastructure.

My research resulted in a PhD in the study of Internet architecture from the University of Michigan in 1999. In 2010, I collaborated with industry and academic partners to complete the largest research study of Internet traffic to date, which explored changes in the interconnection and traffic demands across more than 150 Internet providers around the world over a three-year period.[3] Earlier this year, my company, DeepField, along with academic and industry partners, began work on a large-scale follow-up study to the 2010 work. The facts and conclusions in my statement are largely based on these research efforts.

Ten years ago, the pre-Facebook and pre-Netflix Internet was both much smaller and looked very different than it does today. In the earlier stages of Internet development, almost all traffic travelled across an Internet "core" consisting of 12 large national and international transit providers, including companies like AT&T, Cogent and Level3. The Internet core interconnected the majority of all content providers with the many thousands of consumer access networks around the world such as AOL and EarthLink.

The industry calls these interconnections between providers "peering," though the term has become broadened in recent years to include a range of varied technical and economic models for exchanging traffic. Unlike telephony, which evolved over a century with tariffs defining the payments associated with the exchange of voice calls, the exchange of Internet traffic (*i.e.,* peering) has largely developed without regulation.

Internet providers negotiate terms associated with the exchange of traffic with commercial partners. For example, the service providers in the early Internet core, such as AT&T, exchanged Internet traffic without paying for access or traffic rights, believing that other core transit networks provided similar economic value and had made equivalent levels of infrastructure investment. The industry calls these arrangements settlement-free peering. Similarly, smaller access networks, such as EarthLink, sometimes exchanged Internet traffic with other small access network settlement-free, although the early lack of infrastructure and centralized data centers often

made the infrastructure costs associated with these connections prohibitive.

As a general matter, most Internet companies played narrow technological and economic roles in the early Internet economy. Access networks such as dial-up (*e.g.,* AOL) and cable operators provided last-mile connectivity to enterprise and consumers. Consumers paid access networks for Internet connectivity and, in turn, access networks paid transit providers (such as AT&T) for carriage to other access networks and transit providers. The industry calls these Internet traffic carriage relationships between providers transit peering. Businesses and content providers, such as Netscape, also paid access networks or connected directly to one of the large transit providers.

Over the last ten years, technological advances and market forces have dramatically transformed the landscape of core Internet interconnection. These market forces include consolidation (*e.g.,* Google's acquisition of YouTube, Yahoo's acquisition of Flickr) and the rapid growth in Internet content and advertising revenue. Technical advances include the rapid growth of centralized Internet exchange points (*e.g.,* Equinix, Terremark/ Verizon), content distribution networks (*e.g.,* Akamai, Level3, Limelight) and hosting/cloud providers (*e.g.,* Amazon, Rackspace).

Our research has documented the accelerating impact of these market forces.[3] Whereas Internet traffic was once broadly distributed across thousands of companies, we found that by 2009 half of all Internet traffic originated in less than 150 large content and content distribution companies. By May of 2014, this number had dropped by a factor of five. Today, just 30 companies, including Netflix and Google, contribute on average more than one half of all Internet traffic in the United States during prime time hours.

In addition to the consolidation of content traffic volumes among a smaller group of companies, our research has shown significant changes to interconnection at the core of the Internet. Specifically, we have found an increasing density of direct interconnection between access networks such as EarthLink and content providers like Hulu and Google. Largely, we believe this is a process of disintermediation, or the removal of transit provider "middle-men," as both content and access networks look to achieve greater efficiencies of scale and economy.

By way of example, in 2007, Google used transit providers such as Level3

for more than 70% of its traffic to consumers. In sharp contrast, we found that by 2010 more than 80% of all Google traffic flowed directly between Google infrastructure and access networks such as EarthLink or Verizon. We have observed a similar trend of direct interconnection across a broad range of other cloud and content companies, including Akamai, Level3, and Amazon, further diminishing the role of transit providers. While our data provides visibility into the existence of these direct interconnections, we have limited insight into the substance of those commercial relationships.

Our research has also found a significant degree of vertical integration and blurring of traditional distinctions between companies in the Internet ecosystem. In the emerging new Internet economy, content providers build their own global backbones, cable Internet service providers offer wholesale national transit, and transit Internet providers offer content distribution and cloud/content hosting services. [4] For example, Level3 is both a large transit provider as well as the second largest content distribution network (CDN). Similarly, Comcast is an access provider, a transit provider, and recently announced a content distribution product. Perhaps best illustrating this trend towards integration, we observe that Google is a hosting provider, a cloud provider and recently become a high-speed network access provider in Kansas City, Austin and Provo. Google also continues to sell advertisements and offer a popular Internet search service.

Finally, our ongoing work has found growing diversity and complexity in the Internet content delivery "cyber supply chain." By this, we mean the increasingly diverse set of third-party infrastructure and services supporting the delivery of Internet content. Web sites such as www.netscape.com once came from computers directly owned and managed by the content owners (*e.g.,* Netscape) located in tens of thousands of enterprise machine closets and datacenters around the world. Today, the majority of Internet content leverages third-party content distribution services (*e.g.,* Akamai, Limelight, and Level3), hosting providers (e.g. RackSpace), exchange points (*e.g.,* Equinix) or cloud providers (*e.g.,* Amazon, Google).

For example, Netflix uses Amazon's cloud computing service for movie control and catalog management. Netflix also uses several Internet providers, including Cogent and Level3, for transit to reach some number of consumer access networks. Prior to last year, Netflix contracted with three content distribution networks to deliver their video content (Level3, Akamai, Limelight). More recently, Netflix shifted the majority of its video delivery

from third-party CDN to a newly built private content distribution network. The private Netflix CDN includes computer servers co-located in access network data centers as well as large server farms deployed in Equinix facilities.

I hope my testimony and my research findings help provide the technical context for the increasingly complex economic and engineering issues associated with Internet content delivery and interconnection.

I thank you for your time and attention. I would be pleased to answer any questions you may have.

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[1] http://www.nsfnet-legacy.org/about.php

[2] North American Network Operators Group (NANOG). www.nanog.org

[3] Craig Labovitz, Scott Iekel-Johnson, Danny McPherson, Jon Oberheide, and Farnam Jahanian. "Internet Inter-Domain Traffic". In Proceedings of the ACM SIGCOMM 2010 Conference on Applications, Technologies, Architectures, and Protocols for Computer Communications (SIGCOMM '10), New Delhi, India, August-September 2010.

[4] NetCompetition.org, "A First-Ever Research Study: Estimating Google's U.S. Consumer Internet Usage and Cost. 2008. L. Dignan, "Comcast Feeling the Heat from Competition.'' ZDNet, http://blogs.zdnet.com, October 2007. Greg Goth: New Internet Economics Might Not Make It to the Edge. IEEE Internet Computing 14(1): 7-9 (2010).