

# Evaluating The Competitive Effects Of Mergers Of Internet Backbone Providers

STANLEY M. BESEN

Charles River Associates

JEFFREY S. SPIGEL

King & Spalding

PADMANABHAN SRINAGESH

Charles River Associates\*

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This paper analyzes the usefulness of the traffic measurement methodologies used by the European Commission (EC) and the United States Department of Justice (DOJ) in assessing the competitive effects of mergers of Internet Backbone Providers. The analysis concludes that the traffic ratios used by the EC to estimate market shares when it reviewed the merger application of MCI and WorldCom, and by the EC and the DOJ when they reviewed the proposed merger of Sprint and MCI WorldCom, have significant limitations. In particular, the paper shows that these measurements provide a potentially misleading picture of the effect of a merger of backbone providers even under the assumption that the Internet is a rigid hierarchy, and that this problem is likely to become worse as the use of secondary peering, multihoming, and intelligent content distribution services become more widespread.

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## 1. INTRODUCTION

Since the antitrust review of the merger of the owners of two of the largest Internet Backbone Providers (IBPs) at that time, WorldCom and MCI, the United States Department of Justice (DOJ) and the European Commission (EC) have relied on an analysis of Internet traffic to quantify the competitive effects of IBP mergers. In

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\* Authors' addresses: Dr. Besen, 1201 F. Street N.W., Suite 700, Washington, D.C. 20004. Mr. Spigel, 1730 Pennsylvania Avenue, N.W., Washington, DC 20006-4706. Dr. Srinagesh, 285 Hamilton Avenue, Suite 370, Palo Alto, California 94301.

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reviewing the proposed merger of MCI and WorldCom, the EC [1998] used traffic measurements to support its conclusion that, without a divestiture of internetMCI (MCI's Internet backbone and retail operation), the combined entity would have such a large share of the top level Internet backbone market that it would have an incentive to disadvantage rival IBPs. Later, the EC [2000] and the DOJ [2000] used the same traffic measurements to support their decision to block the proposed merger of MCI WorldCom and Sprint. The analysis in both cases was based on a number of assumptions, one of which was that the Internet could be reasonably modeled as a rigid hierarchy in which each end user obtains service from a single Internet Service Provider (ISP) which, in turn, obtains connectivity to customers of all other ISPs by purchasing transit services from a single IBP, which, in turn, interconnects (or peers) with every other IBP.

However, some observers have argued that the Internet has been moving, and continues to move, from a relatively rigid hierarchy to a looser mesh, with a greater variety of interconnection arrangements. For example, Laffont et al. [2001, p. 288] state that "[t]he Internet does not have a purely hierarchical structure." Similarly, Besen, et al. [2001, p. 296] state that "[t]he Internet's hierarchical structure has evolved from parallel hierarchies to a looser arrangement, in which messages can be exchanged among smaller ISPs without using the backbone of a core ISP." Huston [2001, section 5.1] goes further, arguing in an official Internet Draft that "[t]he business imperatives driving this denser mesh of interconnection in the Internet are irresistible . . ." Examples of the new interconnection arrangements cited by these authors include:

- o Secondary peering, in which smaller IBPs and ISPs interconnect directly to avoid the increased latency that can arise on the networks of the larger IBPs,
- o Multihoming, in which end users obtain connectivity from multiple ISPs and ISPs purchase transit services from multiple IBPs, and
- o Intelligent content distribution techniques (e.g., content distribution networks (CDNs), caching, and mirroring), in which ISPs host content on their own networks to reduce their reliance on IBPs.

The primary focus of this paper is an analysis of the usefulness of the traffic measurement methodologies used by the EC and the DOJ in assessing the competitiveness of the Internet backbone market in general, and the effect of IBP mergers in particular. Our analysis concludes that the traffic ratios used by the EC to estimate market shares when it reviewed the merger application of MCI and WorldCom, and by the EC and the DOJ when they reviewed the proposed merger of Sprint and MCI WorldCom, have significant limitations. In particular, we show that these measurements provide a potentially misleading picture of the effect of a merger of IBPs even under the assumption that the Internet is a rigid hierarchy, and that this problem is likely to become worse as the Internet evolves into a less hierarchical form. We conclude that future analyses of the competitiveness of the Internet backbone market cannot rely on the use of

the traffic ratios that were at the heart of the earlier antitrust reviews and that a more sophisticated analysis is necessary.

In Section 2, we analyze the case of a *completely rigid hierarchy* to demonstrate the shortcomings of the traffic measurements used by the competition authorities even in this extreme case. In our analysis, we identify the markets at issue, and the role of peering relationships in the Internet hierarchy.<sup>1</sup> In Section 3, we review two measures of market power that have been used in recent merger analyses – the traffic ratios used by the EC and the DOJ, and Relative Service Quality (RSQ), which was introduced in Besen et al. [2001]. In this section, we show that, under some fairly restrictive conditions, including the assumption that the Internet is a completely rigid hierarchy, the two measures lead to the same conclusions. We also show, however, that even in a completely rigid hierarchy, the two measures can lead to different conclusions and that the use of the traffic ratios used by the EC and the DOJ can lead to erroneous conclusions about the effects of a merger among IBPs. In Section 4, we show that the shortcomings of the traffic ratios used by the competition authorities can become worse in more complex Internet traffic arrangements that include practices such as secondary peering, multihoming, and intelligent content distribution services.

## 2. A COMPLETELY RIGID INTERNET HIERARCHY

At the bottom of a completely rigid Internet hierarchy are end users, or subscribers. In such a hierarchy, each end user connects to a single ISP. In turn, each ISP purchases transit services from a single IBP. All IBPs interconnect (i.e., establish peering arrangements) with one another at Internet exchanges.

In a transit arrangement, an IBP agrees to deliver all traffic from its ISP customers to any Internet destination, and deliver to its ISP customers all traffic addressed to them from any point of origin. In a peering arrangement, an IBP agrees to deliver to a second IBP all traffic destined to ISP customers in that IBP's hierarchy and to accept all traffic from customers of that IBP to destinations in its hierarchy. Typically, peering arrangements do not involve payments from one IBP to another. In a rigid hierarchy, traffic from a particular end user in one backbone's hierarchy to a particular end user in another's must traverse the peering interface between those two backbones.

In a completely rigid hierarchy, IBPs obtain their Internet reach through peering relationships with one another other and through access to the networks of their ISP customers. ISPs purchase dedicated Internet access, i.e., transit services, from IBPs to obtain connectivity.<sup>2</sup> This hierarchical relationship, where ISPs pay for access to IBPs, is the source of the historical tension among providers in the Internet and served as the basis for the central Internet issue addressed by competition authorities in their analyses of the

merger of WorldCom and MCI and the proposed merger of WorldCom and Sprint -- that is, whether the merger of two IBPs gives the merged entity market power, or a dominant market position, in the market in which transit services are provided.

As noted above, the traffic ratios used by the antitrust authorities to analyze the proposed mergers were based, in part, on the assumption that the Internet is a rigid hierarchy. As we show below, the use of these ratios is inappropriate even under this assumption. Moreover, although the assumption of a rigid hierarchy may have been a reasonably accurate representation at the time of the review of WorldCom's merger with MCI in 1997,<sup>3</sup> it has become significantly less so over time. Several factors account for this change.

First, routing equipment costs have been reduced to levels that permit the establishment of direct (or secondary peering) connections between the so-called second and third tier IBPs and ISPs, thereby reducing the extent to which these providers must rely on a top-level IBP. Second, the rapid growth of commercially provided interconnection points has helped reduce the costs incurred by lower level IBPs in identifying potential secondary peers and establishing peering links with them. Finally, the ability of ISPs to establish multihomed connections, and the introduction of content delivery mechanisms, have enabled lower tier providers, including ISPs and web farms, to build redundancy into their networks, insulating them to an extent from the low quality of Internet traffic exchanges. Indeed, the tension described above has created incentives for ISPs and smaller IBPs to develop and employ these methods to reduce their reliance on the top level IBPs. We show below that the effect of these developments is to make the EC's and DOJ's traffic measurement analyses even more misleading in measuring the competitive effects of a merger between IBPs.

## 2.1 Theory of Anticompetitive Behavior

The merger of MCI and WorldCom marked the first time competition authorities publicly investigated the competitiveness of the Internet in the context of a merger, and the theory developed in that case was later used by the competition authorities in evaluating MCI WorldCom's proposed merger with Sprint and WorldCom's acquisition of Intermedia. At the time the MCI-WorldCom merger was notified with the EC, internetMCI and UUNET (which had been acquired by WorldCom) were two of the leading IBPs. According to the EC [1998, para. 117], their combination would have created an IBP of such a large size that it "could behave to an appreciable extent independently of its IBP competitors..." In particular, the EC argued that combined entity could have raised the costs of its IBP rivals, primarily Sprint and GTE, and engaged in selective price reductions to attract customers from these competitors.

Further, the EC contended, the merger would raise barriers to entry by new backbone entrants since the merged entity would have even less incentive to peer with them than did WorldCom and MCI prior to the merger. Based on this analysis, the merger was allowed to proceed only after the merging parties agreed to divest internetMCI, including its retail operation, prior to closing their transaction.

The EC's theory supporting its decision was that a sufficiently large IBP may have the ability and incentive to exert market power by threatening to terminate or degrade a peering agreement with smaller backbone rivals, or to charge these rivals for peering, which would then permit the merged entity to raise its rivals' costs and increase prices for transit services. This occurs because, in a rigid hierarchy, if a peering interface is terminated or degraded by the large IBP, all traffic that flows over that interface cannot reach its destination over alternative paths. As a result, end users in the smaller IBP's hierarchy will experience a lower quality of service than if they were in the larger IBP's hierarchy. These users are more likely to switch to the larger backbone to take advantage of the better service that it offers, thereby harming the smaller backbone.

These considerations are illustrated in the following example with two IBPs, in which the hierarchy of the larger backbone contains 60% of all Internet end users and the hierarchy of the smaller backbone serves the remaining 40%. If the peering interface between these IBPs were terminated or degraded, the large backbone's customers would lose connectivity (or high quality connectivity) to 40% of the Internet, but would be able to reach (or reach with high quality) 60% of all Internet destinations. Similarly, the smaller backbone's customers would lose connectivity (or high quality connectivity) to 60% of the Internet, and would continue to reach (or reach with high quality) only 40% of all Internet destinations. We define RSQ as the ratio of the proportion of high-quality traffic on one backbone to the corresponding proportion on another backbone *if the interface between them is terminated or degraded*. In the example above, RSQ for the larger backbone is  $60\%/40\% = 1.5$  and RSQ for the smaller backbone is  $40\%/60\% = 2/3$ .

If a peering interface were degraded, any individual customer would be able to obtain high quality service on a larger proportion of its traffic by joining the larger backbone through one of the ISPs that are connected to that backbone. For this reason, Besen et al. [2001] concluded that the RSQ provides an appropriate measure of the relative competitive positions of the two backbones. Although switching costs, such as non-portable email and IP addresses, may reduce the rate at which the small backbone's subscribers would switch to the larger backbone, ISPs that are connected to the larger backbone would still have a competitive advantage in attracting existing and especially new subscribers. Growth in the relative size of the larger backbone, perhaps as the result

of a merger, would further enhance its ability to gain customers, and the market could eventually “tip” to the larger backbone. <sup>4</sup>

## 2.2 WorldCom/MCI

The analysis of the MCI-WorldCom merger by the EC was based primarily on the view that the structure of the Internet was hierarchical. Indeed, in its review of that transaction the EC [1998, para. 22] explicitly noted: “In its early pre-commercial days the Internet had a clear hierarchical structure, with local networks such as internal university networks connected to regional networks which in turn were connected to the long-distance transmission capacity (or the “backbone” link) operated by the NSF.” The EC [1998, para. 41] went on to describe an Internet with multiple backbones, and describe the “top level” of this hierarchy as follows: “Traffic which is progressively defaulted to higher level networks will finally end up in the hands of an ISP who has no one else to whom to turn, and must either assume responsibility on its own account for delivering the traffic across peering interfaces, or return it undelivered. These networks (or the ISPs concerned) are referred to hereon as ‘top-level networks’ or ‘top level ISPs’.” The EC [1998, para. 44] recognized that a large ISP could increase its RSQ *vis a vis* a smaller ISP by terminating its peering relationship with the smaller backbone: “... the right of access to the larger network is far more valuable to the customers of the smaller network than the equivalent rights in the reverse direction. Interconnection to a large network may give a small ISP the opportunity to offer its customers connections to thousands of sites, whereas the existing customers of the larger network gain only a relatively small marginal benefit in terms of access to perhaps no more than a few tens or hundreds of new sites. Consequently the larger network is in a position to determine the terms on which it will interconnect.”

Up to this point, the EC’s analysis closely parallels our earlier analysis of the rigid hierarchy and the importance of RSQ in determining bargaining power. However, in its attempt to quantify the effect of the merger on the competitiveness of the backbone market, rather than employing the analysis described above, the EC used traffic ratios to measure the effect of the proposed merger on market shares.

The EC first identified firms in the backbone market, or the market for top-level connectivity. Based on confidential information provided in response to its requests, the EC [1998, para. 103] concluded that the top-level backbone market included the “big four” IBPs (MCI, WorldCom, Sprint and GTE/BBN (now Genuity)) as well as twelve other IBPs that had settlements-free connectivity with each of the big four.

The EC [1998, para. 109] computed the relative sizes of the backbones using traffic measurements as follows. “The ratio of the market share of network A to the market

share of network B is equal to the ratio of total traffic flowing through network A to total traffic flowing through network B. If both terms of this ratio are divided by the total traffic exchanged between networks A and B, it follows that the ratio of market share of network A to the market share of network B is equal to the ratio of the relative share of network A in the total traffic flowing through network B to the relative share of network B in the total traffic flowing through backbone A. Therefore the market shares can be calculated on the basis of the relative shares of each network in the total traffic going through each network. This prevents the market share calculation being biased by possible differences in measurement methodologies.”

A simple example helps illustrate the procedure. Suppose that one backbone reports a total traffic exchanged with its customers of 200 units, and reports that it exchanges 20 units of traffic with a second backbone over a peering interface. The ratio of total to peering traffic for this backbone is 10. Suppose the second backbone reports exchanging 100 units of traffic with its customers, and 20 units of traffic with the first backbone. The ratio of total to peering traffic for the second backbone is 5. Using the EC’s methodology, the ratio of the first backbone’s market share to that of the second backbone is 10/5. Thus, according to the EC, the first backbone has twice the market share of the second backbone. Once the relative market shares of all IBPs in the market for top-level connectivity are calculated, absolute market shares are easily obtained. In the simple example, if there are only two IBPs, the market share of the first backbone is 2/3 and the market share of the second backbone is 1/3.

Using traffic statistics obtained from each IBP in the relevant market, the EC [1998, para.110] found that “When applying this methodology to a hypothetical market comprising GTE, MCI, Sprint and the WorldCom group, their respective market shares would leave the WorldCom group with [between 50 and 60 %](\*) of such a market, with MCI bringing an additional [between 15 and 25 %](\*), or [between 75 (*sic*) and 85 %](\*) in total.”<sup>5</sup> When the hypothetical market was expanded to include the twelve largest ISPs that had peering relationships with the big four, the EC [1998, para.113] determined that “the market shares would give the WorldCom group some [between 30 and 40 %](\*), with MCI bringing an additional [between 10 and 20 %](\*) and no competitor having more than [between 5 and 15 %](\*). The combined market shares of MCI and the WorldCom group would then be [between 42 and 52 % (*sic*)](\*).” Based in part on this analysis, the EC concluded that the merger would create a dominant position. To win approval of the merger, the parties agreed to the complete divestiture of internetMCI.

### 2.3 MCI WorldCom/Sprint

Almost two years after the MCI-WorldCom merger, the EC [2000], this time joined by the DOJ [2000], used the analytical framework and traffic ratio methodology that it had developed for that merger to evaluate the competitive effects of the proposed merger of MCI WorldCom and Sprint. At the time, WorldCom's UUNET subsidiary was still the largest provider of Internet backbone services in the world, and Sprint's subsidiary SprintLink was the second-largest IBP. The DOJ's complaint alleged, among other things, that the proposed acquisition would substantially lessen competition in violation of Section 7 of the Clayton Act, as amended, 15 U.S.C. § 18, in the Internet backbone services market. According to the complaint, the merger would eliminate Sprint as an IBP, thus lessening competition in an already concentrated market for the provision of top-level or universal Internet connectivity. The DOJ argued that, as a result of the merger, the market power of the combined firm would have been enhanced, thus tipping the Internet backbone market towards monopoly. In addition, DOJ argued that the combined entity would have had the incentive and the capacity to impair the ability of its rivals to compete by raising these rivals' costs and/or degrading the quality of its interconnections to them. Moreover, the DOJ contended that entry barriers were already high and the proposed transaction would make barriers to entry even higher.<sup>6</sup>

Although the EC explicitly recognized the existence of caching, mirroring, and multi-homing in its Decision, it apparently did not believe that the hierarchical structure of the Internet, and thus the competitive impact of the proposed merger, had been altered significantly by these new forms of interconnection that had emerged since its review of the WorldCom/MCI transaction. In light of the impracticalities of being able to litigate in a timely and expedited manner, the parties abandoned the merger in July 2000.

### 2.4 WorldCom/Intermedia

Most recently, on November 30, 2000 the DOJ took similar action based on the same theory in *United States v. WorldCom, Inc. & Intermedia Communications, Inc.*,<sup>7</sup> in which it again required the merging parties to divest Intermedia's Internet backbone business to remedy the alleged competitive concern that would arise from the combination of WorldCom's UUNET and Intermedia's much smaller Internet backbone businesses.

## 3. DO TRAFFIC RATIOS MEASURE MARKET POWER?

The Relative Service Quality (RSQ) of a backbone is a measure of its incentive to engage in the anticompetitive conduct described above. Recall that the RSQ is defined as the proportion of high quality traffic on one backbone to the corresponding proportion on another if the interface between them is terminated or degraded. In general, the RSQ of

a larger backbone will exceed 1, creating a competitive advantage for the larger backbone, and hence an incentive for it to terminate or degrade its peering arrangements. Moreover, an entity created by the merger of two IBPs will have a higher RSQ than either of its constituents, and thus an increased incentive to terminate or degrade its peering interfaces. Thus, RSQ plays a role similar to that of market shares in a more traditional analysis of competition because it measures the incentives of a backbone provider to exercise market power.

Even in a completely rigid hierarchy, the calculation of RSQ in a specific case such as the MCI-WorldCom merger is not straightforward. It requires information both about all traffic that originates in a particular IBP's hierarchy as well as the fraction of that traffic that traverses a particular peering interface. Developing and implementing a uniform reporting plan for several thousand ISPs would be a difficult undertaking. A more practical alternative would rely on sampling and the use of "rules of thumb" to reduce the amount of information that would have to be collected. This sampling approach can be supplemented by relevant information developed by neutral third parties such as CAIDA.<sup>8</sup>

There are several tools that can be used to obtain information on the routes followed by packets in the Internet and, in turn, to develop improved estimates of Relative Service Quality. Ping and traceroute are two such tools. Links to traceroute servers (many free) are listed at [http://www.boardwatch.com/Find\\_Backbone.htm](http://www.boardwatch.com/Find_Backbone.htm). More sophisticated traffic measurement tools developed to support the engineering and maintenance of the Internet infrastructure are available at <http://www.caida.org>. Analyses of BGP4 routing tables can also be used to infer the hierarchical structure of the Internet.<sup>9</sup>

In our view, such an enterprise would be worthwhile because it would lead to an estimate – albeit an imperfect one – of the correct measure of the relative competitive positions of competing backbones. (We explain in Section 4 of this paper that an analysis using these tools would likely demonstrate that that, as a result of secondary peering, multihoming, and content distribution mechanisms, a combination of the two large IBPs would have reduced abilities and incentives to harm rival IBPs). The alternative approach used by the EC, although it is based on more easily accessible information, can lead to a highly misleading picture of the extent and nature of competition even in a rigid hierarchy, as we now show.<sup>10</sup>

The problems that arise from the use of traffic ratios to measure market share can be illustrated by a simple example. Assume that there are two IBPs, the first serving two ISPs each with 20 end users, and the second serving four ISPs each with 10 end users.<sup>11</sup> Assume that each end user communicates equally with every other end user. Since both backbones have an equal number of end users in their hierarchies,  $RSQ = 1$ , so that

neither backbone has an incentive to terminate or degrade its peering arrangement with the other.

Now consider the traffic ratio for the first backbone. An end user connected to an ISP network served by this backbone can communicate directly with any of the other users of the same ISP. Traffic to the remaining 60 Internet subscribers will be sent to the backbone. Of this, traffic to the 40 end users in the other backbone's hierarchy will be sent over the peering interface, and the remaining traffic will be delivered over the backbone's own network to the destination ISP network. The ratio of total to peering traffic for this backbone, which is the EC's measure, is therefore  $60/40$ , or 1.5.

An end user in the second backbone's hierarchy will be able to reach directly only the other 9 end users of the same ISP. Traffic to the remaining 70 end users will be sent to the backbone. Of this, traffic to 40 end users will be sent over the peering interface. The ratio of total to peering traffic for the second backbone is therefore  $70/40$ , or 1.75. Applying the EC's formula, the market share of the first backbone relative to that of the second is  $1.5/1.75 = 6/7$ . Although, as shown by the RSQ, neither IBP has an incentive to terminate or degrade the peering interface between them, the calculated traffic ratio suggests that, because the second backbone has a greater fraction of "on-net" traffic, it is less reliant on peering, has a greater market share and market power, and thus a greater incentive to terminate or degrade the peering arrangement between them.

In this example, the traffic ratio suggests that there is an incentive for one backbone to terminate or degrade the peering interface, while the correct measure, RSQ, shows that there is no such incentive. The reason is, of course, that the relative sizes of the ISPs that are connected to the respective backbone affect the amount of traffic that *reaches the backbone*, thus affecting the traffic ratio, but have no effect on RSQ, which depends only on the proportion of traffic that originates on one branch of the hierarchy that is destined for the other branch, that is on the proportion of total *end user traffic* that traverses the peering interface.

The example establishes that "market shares" as measured by the EC are not related in a straightforward manner to the incentive or ability of an IBP to engage in anticompetitive behavior in its peering relationships. Furthermore, the use of traffic ratios can lead to very large errors. For example, if the first backbone served a single ISP with 40 customers and the second backbone network served 40 ISPs each with one customer, the RSQ would be 1, because the number of end users in each IBP's hierarchy is the same. However, the ratio of total to peering traffic for the first backbone would be 1, while the corresponding ratio for the second backbone would be 2. The EC's approach would suggest that the second backbone's market share was twice that of the first, so that

the likelihood of anticompetitive behavior might appear to be very high, although neither backbone has an incentive to terminate or degrade the peering relationship.

As this discussion makes clear, the use of traffic ratios in an antitrust analysis of a rigid hierarchy can be quite misleading when there is significant variation in the degree of consolidation at lower levels in each backbone's hierarchy. Below, we show that the errors that can result from a reliance on traffic ratios in a completely rigid hierarchy are compounded when looser interconnection structures are considered.

#### 4. A PARTIALLY MESHED INTERNET ARCHITECTURE -- TODAY'S INTERNET STRUCTURE

In this section, we examine the implications of the evolving Internet architecture for the use of traffic ratios in a competitive analysis of the market for backbone services. We describe how technological advances are leading to the rapid growth in the adoption of three practices -- secondary peering, multihoming, and intelligent content distribution services -- that alter the architecture of the Internet by replacing a relatively rigid hierarchical structure with a looser mesh of interconnections. We then present examples that illustrate how the use of the EC traffic ratios in a partially meshed architecture can lead to erroneous conclusions regarding the competitiveness of the backbone "market." We also compare our results with results obtained by Besen et al. [2001] on the effects of structural Internet changes on RSQ.

##### 4.1 Secondary Peering and Traffic Ratios

Secondary peering is a practice in which ISPs connect directly with one another rather than using IBPs for this purpose. The Multi-Lateral Peering Agreement (MLPA) signed by 56 ISPs at the Ameritech NAP (<http://www.aads.net/MPLA>) is one example of secondary peering. Examples of other MLPAs include: the Mountain Area exchange, an MLPA between 6 IBPs (<http://www.themax.net/participants.html>); the Compaq Houston NAP (<http://www.compaq-nap.net>), an MLPA between 5 IBPs; the Edmonton Internet exchange (<http://www.eix.net>), an MLPA between 7 IBPs; the Columbus Internet Exchange (<http://www.cmh-ix.net>), an MLPA of 7 IBPs; and several others.

Typically, an ISP that has established secondary peering arrangements with other ISPs will also purchase transit services from an IBP to reach those ISPs with which it is not directly interconnected. When secondary peering arrangements are established by ISPs in the hierarchies of different IBPs, some traffic that would previously have flowed across (primary) peering interfaces will be delivered over secondary peering connections. Significantly, the diverted traffic will be of high quality even if the primary peering interfaces were terminated or degraded. As has been shown in Besen et al. [2001], the traffic that is terminated or degraded is a larger proportion of a small backbone's total

end user traffic than it is of a larger backbone's total end user traffic. Consequently, the RSQ of a smaller backbone tends to *increase* as use of secondary peering in its hierarchy increases. Other things equal, increases in secondary peering tend to *decrease* the likelihood that large IBPs will terminate or degrade peering interfaces with smaller ones.

Although secondary peering *increases* the RSQ of a smaller backbone, it can decrease the market share of the smaller backbone, as measured by the EC's traffic ratios. Consider the following simple example, illustrated in Figure 1.

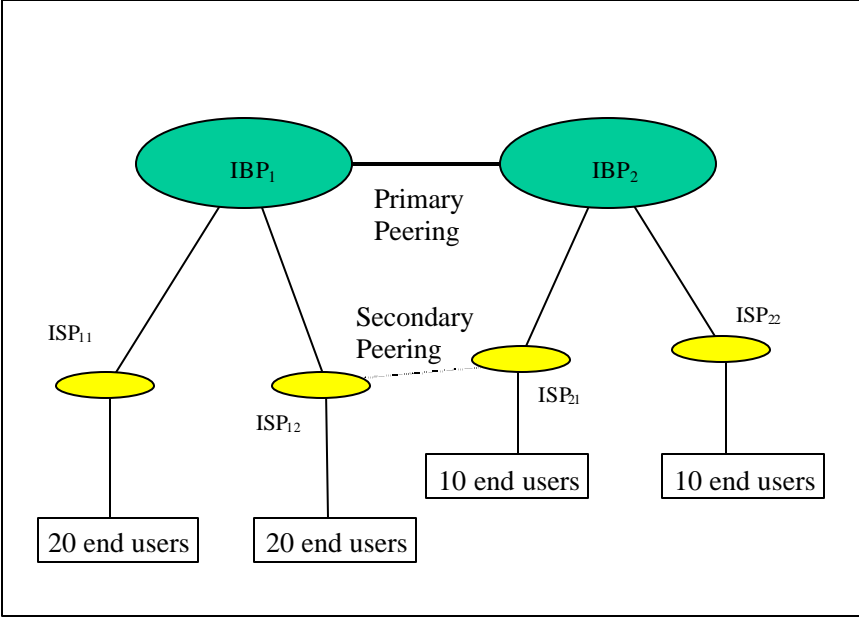


Figure 1

There are two IBPs. IBP<sub>1</sub> serves ISP<sub>11</sub> and ISP<sub>12</sub>, each with 20 end users, and IBP<sub>2</sub> serves ISP<sub>21</sub> and ISP<sub>22</sub> each with 10 end users. End users are assumed to be identical and each end user is assumed to exchange an equal amount of traffic (one unit) with every other end user. Initially, there are no direct interconnections between ISPs.

Each end user in IBP<sub>1</sub>'s hierarchy sends 59 units of traffic to his ISP. The ISP delivers 19 units per subscriber to directly connected end users, and transmits the remaining 40 units to IBP<sub>1</sub>. IBP<sub>1</sub> delivers half of this traffic to the second ISP to which it is connected, and the other half of the traffic (20 units) is transmitted over its peering interface to IBP<sub>2</sub>. The ratio of total to peering traffic for IBP<sub>1</sub> is therefore  $40/20 = 2$ . Each end user in IBP<sub>2</sub>'s hierarchy transmits 59 units of traffic to his ISP, which delivers 9 units of this traffic to directly connected end users. The remaining 50 units per subscriber are transmitted to IBP<sub>2</sub>. Of these 50 units, IBP<sub>2</sub> delivers 10 units to customers of the other ISP to which it is directly connected, and transmits the remaining 40 units over the

peering interface to IBP<sub>1</sub>. The ratio of total to peering traffic for IBP<sub>2</sub> is  $50/40 = 1.25$ . The market share of IBP<sub>1</sub> relative to IBP<sub>2</sub>, as measured by the competition authorities, is, therefore,  $2/1.25 = 1.6$ .

Now assume that an ISP<sub>12</sub> in IBP<sub>1</sub>'s hierarchy establishes a secondary peering relationship with an ISP<sub>21</sub> in IBP<sub>2</sub>'s hierarchy. The calculation of traffic ratios is now more complicated because some traffic from subscribers to an ISP with secondary peering can follow alternative routes from origin to destination.

First consider IBP<sub>1</sub>'s hierarchy. Each end user connected to ISP<sub>11</sub> will transmit 59 units of traffic to other subscribers, 19 of which will be delivered by ISP<sub>11</sub>. The remaining 40 units of traffic per subscriber will be transmitted to IBP<sub>1</sub>. Since ISP<sub>11</sub> has 20 subscribers, a total of 800 units of traffic will be delivered by ISP<sub>11</sub> to IBP<sub>1</sub>. Of this, 400 units will be delivered to ISP<sub>12</sub> and 400 units will be transmitted over the peering interface to IBP<sub>2</sub>. Each subscriber connected to ISP<sub>12</sub> will generate 59 units of traffic. Of this, 19 units will be directly delivered to the subscribers of ISP<sub>12</sub>, 10 units will be transmitted over the secondary peering interface for direct delivery to subscribers of ISP<sub>21</sub>, and 30 units will be transmitted to IBP<sub>1</sub>. Thus, IBP<sub>1</sub> will receive a total of  $(20)(30) = 600$  units of traffic from ISP<sub>12</sub>. Of this, 400 units will be delivered by IBP<sub>1</sub> to the 20 subscribers of ISP<sub>11</sub>, and 200 units will be transmitted over the primary peering interface for delivery to the 10 subscribers of ISP<sub>22</sub>. The total traffic received by IBP<sub>1</sub> is  $1400 - 800$  from ISP<sub>11</sub> and 600 from ISP<sub>12</sub>. The total traffic transmitted over the peering interface is 600. The ratio of total to peering traffic for IBP<sub>1</sub> is therefore  $14/6 = 2.33$ .

Proceeding similarly for IBP<sub>2</sub>, we find that the ratio of total to peering traffic is  $8/6$ . The market share of IBP<sub>1</sub> relative to IBP<sub>2</sub> is therefore  $14/8 = 1.75$ , compared to 1.6 when there was no secondary peering. In the example, when market shares are calculated using traffic ratios, the larger IBP appears to *gain* market power when the extent of secondary peering increases. However, as explained above, secondary peering actually *reduces* the incentive of larger backbones to engage in anticompetitive behavior by reducing the proportion of the traffic that originates in the hierarchies of smaller backbones that must traverse peering interfaces, a result that is shown by the RSQ measure. Clearly, the traffic ratios calculated by the EC can lead to misleading conclusions regarding the competitiveness of the backbone market when the extent of secondary peering changes.

More generally, assume that IBP<sub>1</sub> serves two ISPs, each with N<sub>1</sub> end users and IPB<sub>2</sub> serves two ISPs, each with N<sub>2</sub> end users. It can be shown that the ratio of IBP<sub>1</sub>'s relative market share (calculated using the Commission's traffic ratios) without secondary peering to the same ratio when one ISP connected to IBP<sub>1</sub> peers with an ISP connected to ISP<sub>2</sub> is:

$$\frac{(N_1 + 2N_2)(3N_1 + 2N_2)}{(2N_1 + N_2)(2N_1 + 3N_2)}$$

This ratio can be shown to be less than 1 when N<sub>1</sub> > N<sub>2</sub>, establishing that market shares calculated using traffic ratios are fundamentally flawed: they indicate an increase in the market power of the larger backbone when secondary peering increases, even though the growth of this practice reduces the significance of primary peering interfaces and thus the incentive of the larger backbone to degrade or terminate its peering relationships with the smaller backbone.

As noted above, the traffic ratios used by the competition authorities are not accurate measures of market power even in purely rigid hierarchies. Moreover, as shown here, as the extent of secondary peering grows, these ratios become *increasingly* inaccurate measures of market power. Whether the *additional* inaccuracy in these ratios that results from these developments is significant depends on the quantitative importance of secondary peering.

A preliminary survey of sites where secondary peering takes place suggests that an increasing proportion of Internet traffic is flowing over these interfaces. For example, published statistics obtained from the London Internet Exchange (LINX) (<https://stats.linx.net>) show that traffic increased from about 5 Gbps in May 2001 to about 12 GBps in May 2002. According Odlyzko [undated, p. 7], total Internet traffic has been growing at a considerably slower pace: "When seen over the decade of the 1990s, traffic appears to be doubling about once each year." Taken together, these statistics suggest that there has been a significant increase in the proportion of Internet traffic that traverses the LINX. If this trend holds for other secondary peering interfaces, the ability and incentive of larger backbones to engage in anticompetitive behavior would be reduced.

## 4.2 Multihoming

Multihoming is an arrangement in which an end user or ISP purchases two or more connections to the Internet. With recent reductions in the costs of purchasing and managing routers, and decreases in the charges for private line and frame relay connections, the extent of multihoming has increased to a point where it is common

throughout the Internet. According to Schoolar [2000], “on average, [all] ISPs have more than one connection to a major backbone . . . [with a current] ratio of 1.5 connections for every ISP.” The *Boardwatch Magazine Directory of ISPs* also indicates that in 2000, approximately 34% of all connections sold by the major IBPs were *additional connections*<sup>12</sup> purchased by multihomed ISPs. Moreover, registrations for Autonomous System Numbers (<http://www.arin.net/regserv/asnguide.htm>), which are only requested by an ISP when “it is already multi-homed or will immediately become multi-homed,” have increased significantly since 1999. The trend towards greater multihoming was also noted in General Accounting Office [2001].

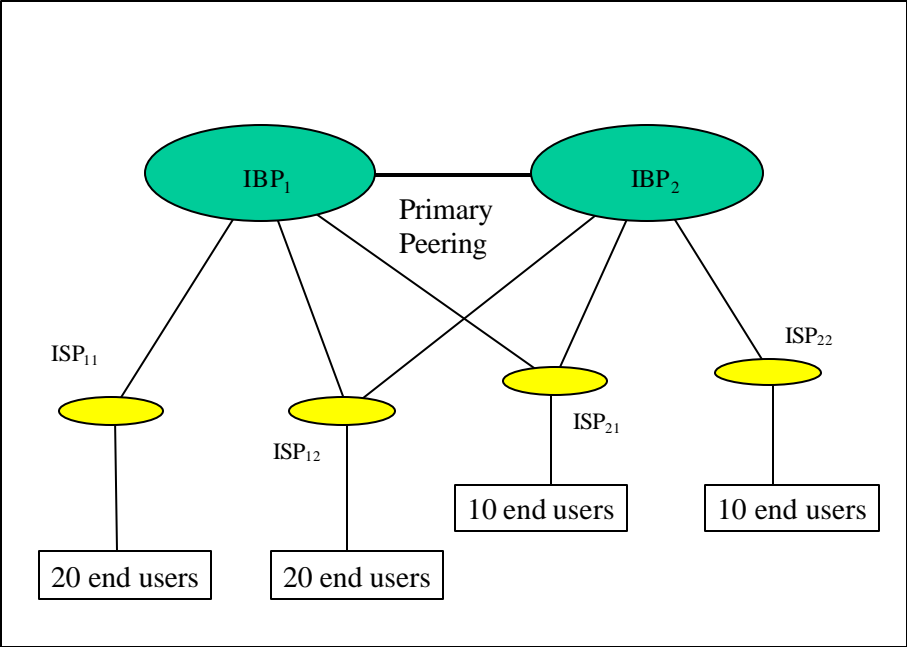


Figure 2

Importantly, this growth has had a competitive effect similar to that of secondary peering by enabling IBPs to divert Internet traffic to other routes if primary peering interfaces are terminated or degraded. Besen et al. [2001] established that increases in multihoming can lead to reductions in the RSQ of a larger backbone, reducing its bargaining power. Below, we analyze the effect of multihoming on the EC’s traffic ratios for a simple example.

Figure 2 depicts multihoming for the simple example developed above. In Figure 2, ISP<sub>12</sub> and ISP<sub>21</sub> are multihomed – each ISP purchases connections from both IBPs. Traffic from customers of these ISPs can follow alternate routes to their destination. Measured traffic ratios differ substantially when alternate routes are chosen.

Suppose, first, that  $ISP_{12}$  and  $ISP_{21}$  agree to exchange traffic with each other using  $IBP_1$ 's transit services. All other traffic (to  $ISP_{11}$  and  $ISP_{22}$ ) is sent to the backbone serving the ISP. Table 1 below shows the calculation of the traffic ratio in this case. Each subscriber of  $ISP_{12}$  transmits 59 units of traffic, for a total of  $(59)(20) = 1180$  units, 380 of which are delivered by  $ISP_{12}$  to its own subscribers. The remaining 800 units are delivered to  $IBP_1$ . Of these, 400 units are delivered to  $ISP_{12}$  over its direct link to  $IBP_1$ , 200 units are delivered to  $ISP_{21}$  over its direct link to  $IBP_1$ , and the remaining 200 units are delivered over the peering interface to  $IBP_2$ . The remaining rows of the table are constructed in similar fashion.

Table I. Traffic flows when $ISP_{12}$ and $ISP_{21}$ exchange traffic using $IBP_1$ .				
All other traffic follows the most direct route.				
	$IBP_1$		$IBP_2$	
Traffic sent by	Traffic Received	Sent to $IBP_2$	Traffic Received	Sent to $IBP_1$
$ISP_{11}$	$40*20=80$	$10*20=200$	0	0
$ISP_{12}$	$30*20=600$	0	$10*20=200$	0
$ISP_{21}$	$40*10=400$	0	$10*10=100$	0
$ISP_{22}$	0	0	$50*10=500$	$20*10=200$
Total	1800	200	800	200
Traffic Ratio	$1800/200=9$		$800/200=4$	

In this example,  $IBP_1$  has a traffic ratio of 9, while  $IBP_2$  has a traffic ratio of 4. According to the EC's methodology, the market share of  $IBP_1$  is 2.25 times the share of  $IBP_2$ .

Next, suppose that  $ISP_{12}$  and  $ISP_{21}$  agree to exchange traffic using  $IBP_2$ , while all other traffic is sent by the most direct route. Traffic flows in this case are shown by Table 2.

Table II. Traffic flows when $ISP_{12}$ and $ISP_{21}$ exchange traffic using $IBP_2$ .				
All other traffic follows the most direct route.				
	$IBP_1$		$IBP_2$	
Traffic sent by	Traffic Received	Sent to $IBP_2$	Traffic Received	Sent to $IBP_1$
$ISP_{11}$	$40*20=80$	$10*20=200$	0	0
$ISP_{12}$	$20*20=400$	0	$20*20=400$	0
$ISP_{21}$	$20*10=200$	0	$30*10=300$	0
$ISP_{22}$	0	0	$50*10=500$	$20*10=200$
Total	1400	200	1200	200

Traffic Ratio	$1400/200=7$	$1200/200=6$
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According to the EC's methodology, the market share of IBP<sub>1</sub> is 1.17 times that of IBP<sub>2</sub>. In this example based on multihoming, the actual routes taken by packets can vary from hour to hour, day to day and month to month. A traffic ratio calculated over a relatively small period (such as two weeks) is likely to reflect routing choices made in that period. The actual routes taken by packets may be the result of factors such as the operating status of the links connecting the ISPs to the backbone that have little to do with the market power of the larger backbone. In particular, the decisions of ISP<sub>21</sub> and ISP<sub>12</sub> to change their routing policies can have a large effect on the measurement of the relative market share of IBP<sub>1</sub> obtained by the competition authorities – almost doubling it from 1.17 to 2.25. However, this change does not correspond to a change in the market power of either backbone, since the latter is not affected by the short-term routing option chosen by ISPs.

In addition, when IBP<sub>1</sub> terminates or degrades its peering link with IBP<sub>2</sub>, *its own* end user subscribers have an incentive to switch to either ISP<sub>11</sub> or ISP<sub>21</sub>. New subscribers would also prefer one of these downstream ISPs to IBP<sub>1</sub>. IBP<sub>1</sub> would lose downstream subscribers to multihomed ISPs if it degraded its peering link. This would further blunt the incentives of the larger backbone to terminate or degrade its peering relationships with smaller ISPs. The traffic ratio used by the EC is insensitive to these considerations.

### 4.3 Caching, Mirroring, and Content Distribution Services

Since Sprint's attempted merger with WorldCom, the development of caching, mirroring, and intelligent content distribution services, each of which reduce the proportion of end user traffic that must traverse peering interfaces, have become more widespread.<sup>13</sup> For example, Akamai, AT&T, Cable & Wireless (which acquired Digital Island and the domestic assets of Exodus), EpicRealm, iBEAM, and Inktomi all actively market content-based delivery services.

Caching functions by storing copies of frequently accessed documents at locations on the network closer to the requesting host. By adding storage and a limited amount of processing capacity at different points in a local, regional, or national network, end-users and ISPs may reduce their reliance on IBPs for data transport. For example, Geoff Huston, a Telstra engineer, has noted that a well-configured cache may reduce need for data transport by 20-35%.<sup>14</sup> Mirroring involves the additional increment of processing power to actually replicate a website at a point on the network closer to selected end-users.

These technological developments, which facilitate distributed content services, do not completely substitute for transit services, but rather reduces the ability of an IBP to lower the quality of service experienced by a rival's customers by terminating or degrading a peering interface. Like secondary peering and multihoming, however, they permit an increasing fraction of all Internet traffic to travel from origin to destination without traversing peering interfaces. And, as in those cases, when alternative routes that bypass peering interfaces are available, traffic ratios become increasingly unreliable indexes of market power.

## 5. CONCLUSIONS

The traffic ratios used by the competition authorities to analyze the Internet backbone market are severely limited even when the Internet is assumed to have a completely rigid hierarchical structure and recent technological advances that enable a greater variety of interconnection arrangements have not only further reduced the utility of these ratios, but have also raised questions about the continued relevance of the theories that provided the foundation for the antitrust authorities' opposition to previous mergers of IBPs. To address the questions that are of interest to the competition authorities requires a better understanding of the routes taken by end user traffic and the proportion of total end user traffic that can bypass the peering arrangements of the merging parties.

There is an urgent need for work on tools, data, and analyses that can be used to evaluate mergers involving IBPs using measures that accurately quantify the nature and extent of competition. Until such tools and data are available, however, the continued reliance by the competition authorities on traffic ratios will result in measures that, while relatively easily obtained, do not accurately reflect the incentives of participants in the Internet backbone market to engage in anticompetitive behavior and are likely to become even more inaccurate over time.

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1. Although this benchmark is a useful abstraction that captures important characteristics of the early Internet, it should not be taken as a literal description of the Internet's structure even at that time.
  2. Because the Internet is not, in fact, a completely rigid hierarchy, some providers offer ubiquitous connectivity by establishing peering arrangements with some IBPs and purchasing transit services from

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others. These smaller second and third tier IBPs are distinguished from the top level IBPs, in part because they often pay these IBPs for “peering”. The role of the smaller IBPs is examined in greater detail below.

3. Although some of the developments that have loosened the Internet hierarchy had begun at that time, most were still in a nascent stage and apparently had little effect on the way in which the mergers were evaluated by the competition authorities.
4. Note that this does not mean that a larger backbone will always degrade its peering interfaces with smaller backbones, because small increases in relative service quality may be more than offset by large reductions in absolute service quality, resulting in lower subscriber willingness to pay and lower profits.
5. Asterisks indicate material in square brackets that was redacted in a public version of the document.
6. For more on the EC’s rationale, see Piffaut et al. [2001].
7. 2001 -2 Trade Cases (CCH) ¶ 73,350 (D.D.C. 2001).
8. <http://www.caida.org>. Information from such third parties may be desirable both because the same measurement tool would be used in measuring traffic for all backbones and because the information is less subject to manipulation. For a description of some problems in ascertaining the topology of the Internet, see Huffaker et al. [undated].
9. For such an analysis, see Gao [2000].
10. Below, we show how this problem is made even worse by the developments such as secondary peering, multihoming, and intelligent content distribution services.
11. For simplicity, the IBPs are assumed to have no end user customers.
12. Additional connections are second, third or subsequent connections purchased by multihomed ISPs.
13. “Companies reduce reliance on backbone service—and thus increase transmission speed—by caching frequently used content on their servers. In addition, companies have emerged that specialize in caching frequently accessed content and storing it in varied geographic locations, thus making it more quickly accessible to customers. GAO Report, Page 25.
14. See [http://www.cisco.com/warp/public/759/ipj\\_2-3/ipj\\_2-3\\_webcaching.html](http://www.cisco.com/warp/public/759/ipj_2-3/ipj_2-3_webcaching.html)

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