January 2007

Economics of the Internet

Nicholas Economides
New York University, economides@stern.nyu.edu

NET Institute*

www.NETinst.org

Working Paper #07-01

January 2007

Economics of the Internet

Nicholas Economides
Stern School of Business, NYU

Forthcoming, *Palgrave Dictionary*

Economics of the Internet

By Nicholas Economides*

Abstract

We discuss salient economic aspects of the Internet, including the possible abolition of net neutrality by local broadband access networks as well as potential incompatibilities and degradation of connectivity in the Internet backbone.

* Professor of economics, Stern School of Business, New York University, www.stern.nyu.edu/networks/ , email: economides@stern.nyu.edu , and Executive Director, NET Institute, www.NETinst.org .

Economics of the Internet

1. Description of the Structure of the Internet

The Internet is a global network of interconnected networks that connect computers. The Internet allows data transfers as well as the provision of a variety of interactive real-time and time-delayed telecommunications services. Internet communication is based on common and public protocols. Hundreds of millions of computers are presently connected to the Internet. Figure 1 shows the expansion of the number of computers connected to the Internet.

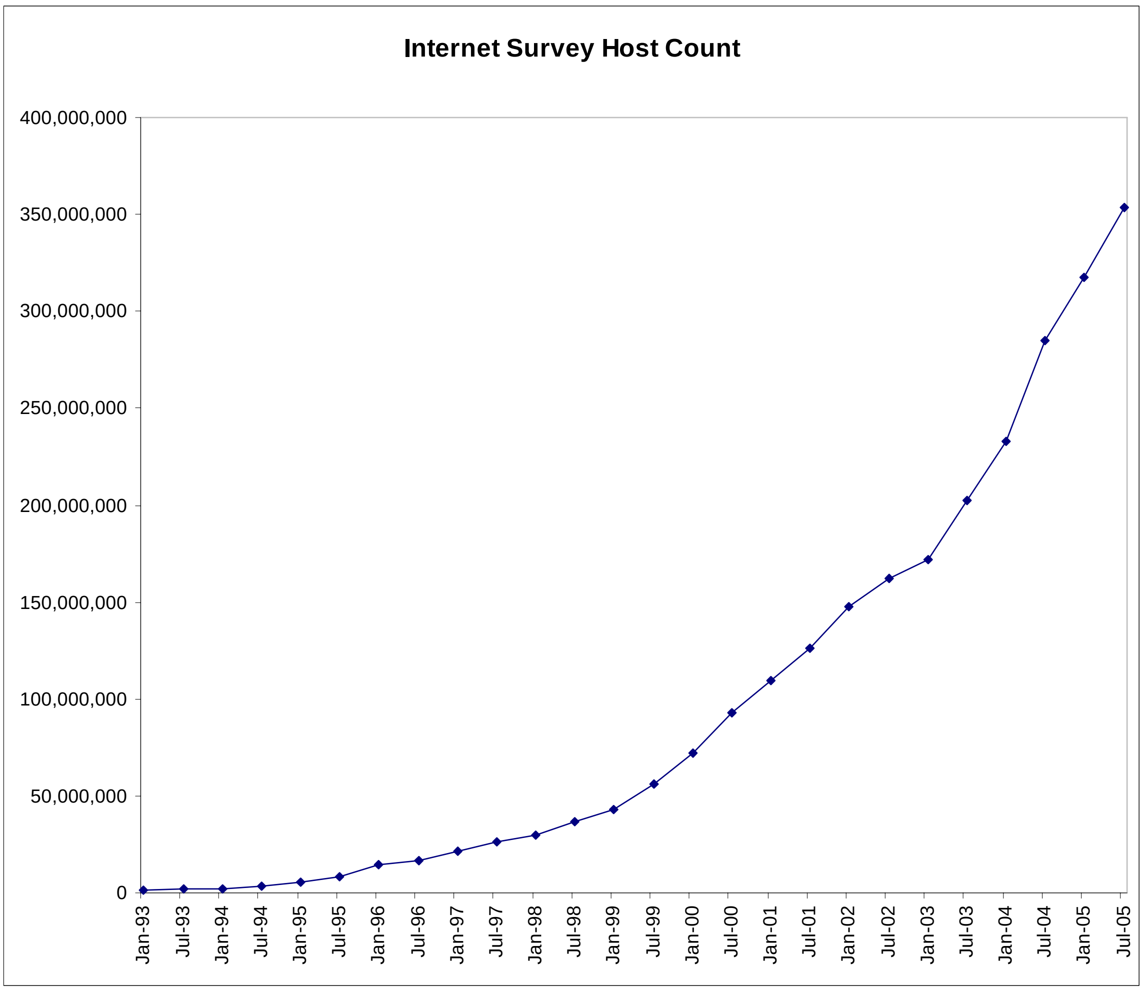


Figure 1

The vast majority of computers owned by individuals or businesses connect to the Internet through commercial Internet Service Providers ("ISPs"). Educational institutions and government departments are also connected to the Internet but typically do not offer commercial ISP services. Users connect to the Internet either by dialing their ISP, connecting through cable modems, residential DSL, or through corporate networks. Typically, routers and switches owned by the ISP send the caller's packets to a local Point of Presence "POP" of the Internet. Dial-up, cable modem, and DSL access POPs as well as corporate networks dedicated access circuits connect to high speed hubs. High speed circuits, leased from or owned by telephone companies, connect the high speed hubs forming an "Internet Backbone Network."

The Internet is based on three basic separate levels of functions of the network:

(i) the hardware/electronics level of the physical network;

(ii) the (logical) network level where basic communication and interoperability is established; and

(iii) the applications/ services level.

Thus, the Internet separates the network interoperability level from the applications/services level. Unlike earlier centralized digital electronic communications networks, such as CompuServe, AT&T Mail, Prodigy, and early AOL, the Internet allows a large variety of applications and services to be run "at the edge" of the network and not centrally.

2. <u>Residential Broadband Access Networks and Net Neutrality</u>

Users pay ISPs for access to the whole Internet. Similarly, ISPs pay backbones for access to the whole Internet. ISPs pay per month for a pipe of a certain bandwidth, presumably according to their expected use. When digital content, for example, is downloaded by consumer A from provider B, both sides, that is, both A and B pay. Consumer A pays to his ISP through his monthly subscription, and provider B pays similarly. In turn, ISPs pay to their respective backbones through their monthly subscription. The present regime on the Internet does not distinguish in terms of price (or in any other way) between bits or information packets depending on the services that these bits and packets are used for. This regime, called "net neutrality," has prevailed on the Internet since its inception. Presently, a bit or information packet used for Voice Over Internet Protocol ("VOIP"), for search, email, for an image, or for a video is priced equally as a part of the large number of packets that correspond to the subscription services of the originating and terminating ISP.

Taking advantage of a change in regulatory rules by the Federal Communications Commission that reclassified the Internet as an "information service" rather than a "telecommunications service," AT&T, Verizon and Cable TV networks advocate price discrimination based on which application and on which provider the bits they transport come from. These local broadband access networks would like to abolish the regime of net neutrality and substitute for it a complex pricing schedule where, besides the basic service for transmission of bits, there will be additional charges by the Internet access network levied to the originating party (such as Google, Yahoo, or MSN) even when the application provider is not directly connected to the local access network.

The imposition of price discrimination on the provider side of the market and not on the subscriber is a version of two-sided pricing. It is uniquely possible to firms operating within a network structure. Besides traditional networks, such two-sided pricing is also possible by intermediaries in exchange networks (such as the exchanges themselves). There is presently considerable debate on the legality as well as the efficiency properties of the implementation of such complex pricing strategies by broadband Internet access networks mainly because of the very considerable market power of such firms.

Residential retail broadband Internet access customers may well have difficulty changing ISPs. 99% of the US households are offered Internet access by at most two firms: a telephone company through Digital Subscriber Line (“DSL”) and a cable TV company through a cable “modem,” and many households are facing a monopoly of either cable or DSL. There are also switching costs to residential customers, such as changing equipment. Finally residential customers are much more affected by contracts that bundle broadband Internet access with other services such as telecommunications and cable television.

As discussed earlier, the Internet under net neutrality separated the network layer from the applications/services layer. This allowed firms to innovate “at the edge of the network” without seeking approval from network operator(s). The decentralization of the Internet based on net neutrality facilitated innovation resulting in big successes such as Google, MSN, Yahoo, Skype, etc. Net neutrality also increased competition among the applications and services “at the edge of the network” which did not need to own a network to compete. Additionally, the existence of network effects on the Internet implies that efficient prices to users on both sides (consumers and applications) should be lower than in a market without network effects. Instead we see an attempt to increase prices that will reduce network effects and innovation.

Abolition of net neutrality raises both horizontal and vertical antitrust issues. Starting with horizontal issues, last mile carriers (who are in duopoly or monopoly) may reduce capacity of "plain" broadband Internet access service and/or degrade it so that they can establish a "premium" service for which they will charge additionally content/applications provider. Coordinated reduction of capacity in "plain" service is reminiscent of cartel behavior. In general, the coordinated introduction of price discrimination schemes may reduce output, and that would reduce total surplus. Therefore introduction of coordinated price discrimination may have anti-competitive consequences.

There is a also a variety of potentially anti-competitive vertical effects. For example, a carrier may favor its own content or application over that of independent. VOIP provided over broadband Internet competes with traditional circuit-switched service provided by AT&T and Verizon and could be subject to discrimination. Additionally, both AT&T and Verizon are gearing to distribute video, and could favor their video service over that of others. But the anti-competitive concerns are hardly limited to products and services currently provided by the firms with market power in the access market. The carriers can also leverage market power in broadband access to the content or applications markets through contractual relationships. For example, a carrier can contract with an Internet search engine to put it in "premium" service while searches using other search engines have considerable delays using "plain" service. The question posed in 2007 in front of US Congress is whether it should intervene by imposing non-discrimination restrictions or wait instead for antitrust suits to filed and resolved. The crucial role of the Internet in US economic growth argues in favor of pre-emptive restrictions.

3. <u>Backbone Issues</u>

Backbone networks provide transport and routing services for information packets among high speed hubs on the Internet. Backbone networks vary in terms of their geographic coverage. There is wide variance of ISPs in terms of their subscriber size and the network they own. However, irrespective of its size, an ISP needs to interconnect with other ISPs so that its customers will reach all computers/nodes on the Internet. That is, interconnection is necessary to provide universal connectivity on the Internet which is demanded by users. Internet networks interconnect in two ways: (i) private bilateral interconnection; and (ii) interconnection at public NAPs. Private interconnection points and public NAPs are facilities that provide collocation space and a switching platform so that networks are able to interconnect. Interconnection services are complementary to Internet transport. In a sense, the Internet backbone networks are like freeways and the NAPs are like the freeway interchanges.

Internet networks have contracts that govern the terms under which they pay each other for connectivity. Payment takes two distinct forms, (i) payment in dollars for "transit"; and (ii) payment in kind, *i.e.*, barter, called "peering." Connectivity arrangements among ISPs encompass a seamless continuum, including ISPs that rely exclusively on transit to achieve connectivity, ISPs that use only peering to achieve connectivity, and everything in between. Although there are differences between transit and peering in the specifics of the payments method, and transit includes services to the ISP not provided by peering, these two are essentially alternative payment methods for connectivity. The transport and routing that backbone networks offer do not necessarily differ depending on whether cash (transit) or barter (peering) is used for payment.

Under transit, a network X connects to network Y with a pipeline of a certain size, and pays network Y for allowing X to reach all Internet destinations. Under transit, network X pays Y to reach not only Y and its peers, *but also any other network*, such as network Z by passing through Y, as in the diagram below.

X------------Y-=-=-=-=-=-Z

Under peering, two interconnecting networks agree not pay each other for carrying the traffic exchanged between them as long as the traffic originates and terminates in the two networks. Referring to the diagram above, if X and Y have a peering agreement, they exchange traffic without paying each other as long as such traffic terminating on X originates in Y, and traffic terminating on Y originates in X. If Y were to pass to X traffic originating from a network Z that was not a customer of Y, Y would have to pay a transit fee to X (or get paid a transit fee by X), i.e., it would not be covered by the peering agreement between X and Y.

Although the networks do not exchange money in a peering arrangement, the price of the traffic exchange is not zero. If two networks X and Y enter into a peering agreement, it means that they agree that the cost of transporting traffic from X to Y and vice versa that is incurred within X is roughly the same as the cost of transporting traffic incurred within Y. These two costs have to be roughly equal if the networks peer, but they are not zero.

The decision as to whether interconnection takes the form of peering or transit payment is a commercial decision. Peering is preferred when the cost incurred by X for traffic from X to Y and Y to X is roughly the same as the cost incurred by Y for the same traffic. If not, the networks will use transit. As I will explain below, the decision of whether to peer or not depends crucially on the geographic coverage of the candidate networks.

Generally, peering does not imply that the two networks should have the same size in terms of the numbers of ISPs connected to each network, or in terms of the traffic that each of the two networks generate. If two networks, X and Y, are similar in terms of the types of users to whom they sell services, the amount of traffic flowing across their interconnection point(s) will be roughly the same, irrespective of the relative size of the networks. For example, suppose that network X has ten ISPs and network Y has one ISP. If all ISPs have similar features, the traffic flow from X to Y is generally equal to the traffic flow from Y to X.

What determines whether a peering arrangement is efficient for both networks is the *cost* of carrying the mutual traffic within each network. This cost will depend crucially on a number of factors, including the geographic coverage of the two networks. Even if the types of ISPs of the two networks are the same as in the previous example (and therefore the traffic flowing in each direction is the same), the cost of carrying the traffic can be quite different in network X from network Y. For example, network X (with the ten ISPs) may cover a larger geographic area and have significantly higher costs per unit of traffic than network Y. Then network X would not agree to peer with Y. These differences in costs ultimately would determine the decision to peer (barter) or receive a cash payment for transport.

Where higher costs are incurred by one of two interconnecting networks because of differences in the geographic coverage of each network, peering would be undesirable from the perspective of the larger network. Similarly, one expects that networks that cover small geographic areas will only peer with each other. Under these assumptions, who peers with whom is a consequence of the extent of a network's geographic coverage, and may not have any particular strategic connotation. In a theoretical model, Milgrom *et al*. (2000) shows how peering can emerge under some circumstances as an equilibrium in a bargaining model between backbones.

Structural conditions for Internet backbone services (ease of expansion and entry) ensure small barriers to entry and expansion and easy conversion of other transport capacity to Internet backbone capacity. As discussed later on, raw transport capacity as well as Internet transport capacity have grown dramatically. Transport capacity is almost a commodity because of its abundance. The business environment for Internet backbone services is competitive. Generally, ISPs buying transport services face flexible transit contracts of relatively short duration. This is reflected in competitive pricing. Economides (2006a) shows that AT&T and MCI had almost identical prices for transit in 1999 when AT&T's backbone business was significantly smaller than MCI's.

ISPs are not locked-in by switching costs of any significant magnitude. Thus, ISPs are in good position to change providers in response to any increase in price, and it would be very difficult for a backbone profitably to increase price. Moreover, a large percentage of ISPs has formal agreements that allow them to route packets through several backbone networks and are able to control the way the traffic will be routed (multi-homing).

When an ISP reaches the Internet through multiple backbones, it has additional flexibility in routing its traffic through any particular backbone. A multi-homing ISP can easily reduce or increase the capacity with which it connects to any particular backbone in response to changes in prices of transit. Thus, multi-homing increases the firm-specific elasticity of demand of a backbone provider. Therefore, multi-homing severely limits the ability of any backbone services provider to profitably increase the price of transport. Any backbone increasing the price of transport will face a significant decrease in the capacity bought by multi-homing ISPs.

Large Internet customers also use multiple ISPs, which is called "customer multi-homing." They have chosen to avoid any limitation on their ability to switch traffic among suppliers even in the very shortest of runs. Customer multi-homing has similar effects as ISP multi-homing in increasing the firm-specific elasticity of demand of a backbone provider and limiting the ability of any backbone services provider to profitably increase the price of transport.

Like any network, the Internet exhibits network effects. Network effects are present when the value of a good or service to each consumer rises as more consumers use it, everything else being equal – see Economides (1996), Farrell and Saloner (1985), Katz and Shapiro (1985), and Liebowitz and Margolis (1994). In traditional telecommunications networks, the addition of a customer to the network increases the value of a network connection to all other customers, since each of them can now make an extra call. On the Internet, the addition of a user potentially

(i) adds to the information that all others can reach;

(ii) adds to the goods available for sale on the Internet;

(iii) adds one more customer for e-commerce sellers;

(iv) adds to the collection of people who can send and receive e-mail or otherwise interact in through the Internet.

Thus, the addition of an extra computer node increases the value of an Internet connection to each connection.

In networks of interconnected networks, there are large social benefits from the interconnection of the networks and the use of common standards. A number of networks of various ownership structures have harnessed the power of network externalities by using common standards. Examples of interconnected networks of diverse ownership that use common standards include the telecommunications network, the network of fax machines, and the Internet. Despite the different ownership structures in these three networks, the adoption of common standards has allowed each one of them to reap huge network-wide benefits.

As the variety and extent of the Internet's offerings expand, and as more customers and more sites join the Internet, the value of a connection to the Internet rises. Because of the high network externalities of the Internet, consumers on the Internet demand universal connectivity, that is, to be able to connect with every web site on the Internet and to be able to send electronic mail to anyone. This implies that every network must connect with the rest of the Internet in order to be a part of it. The demand for universal connectivity on the Internet is stronger than the demand of a voice telecommunications customer to reach all customers everywhere in the world. In the case of voice, it may be possible but very unlikely that a customer may buy service from a long distance company that does not include some remote country because the customer believes that it is very unlikely that he/she would be making calls to that country. On the Internet however, one does not know where content is located. If company A did not allow its customers to reach region B or customers of a different company C, customers of A would never be able to know or anticipate what content they would be missing. Thus, consumers' desire for Internet universal connectivity is stronger than in voice telecommunications. Additionally, because connectivity on the Internet is two-way, a customer of company A would be losing exposure of his/her content (and the ability to send and receive e-mails) to region B and customers of company C. It will be difficult for customer A to calculate the extent of the losses accrued to him/her from such actions of company A. Thus, again, customers on the Internet require universal connectivity.

In markets with network externalities, firms may create bottleneck power by using proprietary standards. A firm controlling a standard needed by new entrants to interconnect their networks with the network of the incumbent may be in a position to exercise market power – see Economides (2006b). Often a new technology will enter the market with competing incompatible standards. Competition among standards may have the snowball characteristic attributed to network externalities.

Economics literature has established that using network externalities to affect market structure by creating a bottleneck requires three conditions -- see Economides (1996a, 1989), Farrell and Saloner (1985), Katz and Shapiro (1985):

(i) Networks use proprietary standards;

(ii) No customer needs to reach nodes of or to buy services from more than one proprietary network;

(iii) Customers are captives of the network to which they subscribe and cannot change providers easily and cheaply.

First, without proprietary standards, a firm does not have the opportunity to create the bottleneck. Second, if proprietary standards are possible, the development of proprietary standards by one network isolates its competitors from network benefits, which then accrue only to one network. The value of each proprietary network is diminished when customers need to buy services from more than one network. Third, the more consumers are captive and cannot easily and economically change providers, the more valuable is the installed base to any proprietary network. I show below that these conditions fail in the context of the Internet backbone.

For example, if universal connectivity were not offered by a backbone network, a customer or its ISP would have to connect with more than one backbone. This would be similar to the period 1895-1930 when a number of telephone companies run disconnected networks. Eventually most of the independent networks were bought by AT&T which had a dominant long distance network. The refusal of AT&T to deal and interconnect with independents was effective because of three key reasons: (i) AT&T controlled the standards and protocols under which its network ran; (ii) long distance service was provided exclusively by AT&T in most of the United States; and (iii) the cost to a customer of connecting to both AT&T and an independent was high. None of these reasons apply to the Internet. The Internet is based on public protocols. No Internet backbone has exclusive network coverage of a large portion of the United States. Finally, connecting to more than one backbone (multi-homing) is a common practice by many ISPs and does not require big costs. And ISPs can interconnect with each other through secondary peering as explained later. Thus, the economic factors that allowed AT&T to blackmail independents into submission in the first three decades of the 20th century are reversed in today's Internet backbone and therefore would not support a profitable refusal to interconnect by any backbone.

The Internet fails to fulfill any of the three necessary conditions stated above under which a network may be able to leverage network externalities and create a bottleneck. First, there are no proprietary standards on the Internet, so the first condition fails. The scenario of standards wars is not at all applicable to Internet transport, where full compatibility, interconnection, and interoperability prevail. For Internet transport, there are no proprietary standards. There is no control of any technical standard by service providers and none is in prospect. Internet transport standards are firmly public property -- see Kahn and Cerf (1999) and Bradner (1999). As a result, any seller can create a network complying with the Internet standards -- thereby expanding the network of interconnected networks -- and compete in the market.

In fact, the existence and expansion of the Internet and the relative decline of proprietary networks and services, such as CompuServe, can be attributed to the conditions of interoperability and the tremendous network externalities of the Internet. America On Line ("AOL"), CompuServe, Prodigy, MCI and AT&T folded their proprietary electronic mail and other services into the Internet. Microsoft, thought to be the master of exploiting network effects, made the error of developing and marketing the proprietary Microsoft Network ("MSN"). After that product failed to sell, Microsoft re-launched Microsoft Network as an Internet Service Provider, adhering fully to the public Internet standard. This is telling evidence of the power of the Internet standard and demonstrates the low likelihood that any firm can take control of the Internet backbone by imposing its own proprietary standard.

Second, customers on the Internet demand *universal connectivity*, so the second condition above fails. Users of the Internet do not know in advance what Internet site they may want to contact or to whom they might want to send e-mail. Thus, Internet users demand from their ISPs and expect to receive universal connectivity. This is the same expectation that users of telephones, mail, and fax machines have: that they can connect to any other user of the network without concern about compatibility, location, or, in the case of telephone or fax, any concern about the manufacturer of the appliance, the type of connection (wireline or wireless) or the owners of the networks over which the connection is made. Because of the users' demand for universal connectivity, ISPs providing services to end users or to web sites must make arrangements with other networks so that they can exchange traffic with *any* Internet customer.

Third, there are no "captive" ISPs on the Internet, so the third condition fails, for a number of reasons:

(i) ISPs can easily and with low cost migrate all or part of their transport traffic to other network providers;

(ii) Many ISPs already purchase transport from more than one backbone to guard against network failures and for competitive reasons (ISP "multihoming");

(iii) Many large web sites / providers use more than one ISP for their sites ("customer multihoming");

(iv) Competitive pressure from their customers makes ISPs agile and likely to respond quickly to changes in conditions in the backbone market.

Competitive conditions imply that significant price increase, or raising rivals' costs or degrading interconnection are unlikely to be profitable on the Internet backbone. If the large Internet backbone connectivity provider's strategy were to impose equal increases in transport costs on all customers, the response of other backbone providers and ISPs will be to reduce the traffic for which they buy transit from the large Internet Backbone Provider ("IBP,") and to instead reroute traffic and purchase more transit from each other. Thus, in response to a price increase by the large Internet backbone connectivity provider, other IBPs and ISPs reduce the traffic for which they buy transit from the large IBP down to the minimum level necessary to reach ISPs that are *exclusively* connected to the large IBP. All other IBPs and ISPs exchange all other traffic with each other bypassing the large IBP network.

Figure 2 shows the typical reaction of an increase in the price of a large IBP, and illustrate why the strategy of increasing price is unprofitable. Consider, for example, a situation where, prior to the price increase, four ISPs (1 to 4) purchase transit from IBP 0 which considers increasing its price. Two of these ISPs (ISP 2 and ISP 3) peer with each other. ISP 1 and ISP 4 buy transit capacity for all their traffic to IBP 0 and the other three ISPs. ISP 2 and ISP 3 buy transit capacity for all their traffic to ISP 0, ISP 1 and ISP 4.

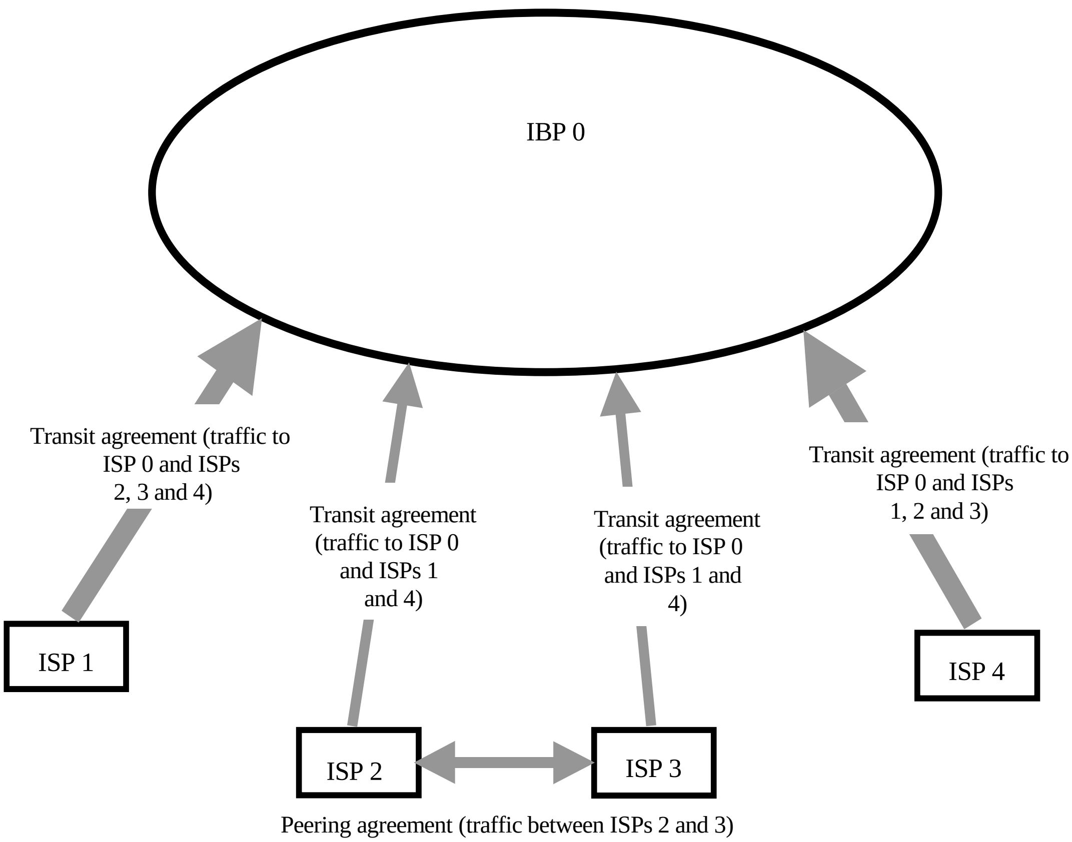
Now suppose that, IBP 0 increases its transit price. In response, ISP 1 and ISP 4 decide to reduce the traffic for which they buy transit from IBP 0, and instead to re-route some of their traffic and purchase more transit from ISP 2 and ISP 3 respectively. Because of the peering relationship between ISP 2 and ISP 3, all traffic from ISP 1 handed to ISP 2 will reach ISP 3 as well as ISP 4 who is a customer of ISP 3. Similarly, by purchasing transit from ISP 3, ISP 4 can reach all the customers of ISP 1, ISP 2 and

ISP 3. Thus, in response to the price increase of IBP 0, each of the ISPs 1, 2, 3, and 4 will reduce the amount of transit purchased from the IBP 0. Specifically, each of the ISPs buys from IBP 0 only capacity sufficient to handle traffic to the customers of network 0. This may lead to a considerable loss in revenues for IBP 0, rendering the price increase unprofitable. The big beneficiaries of the price increase of IBP 0 are peering ISPs 2 and 3 who now start selling transit to ISPs 1 and 4 respectively and become larger networks.

In response to a price increase by the large IBP, rivals would be able to offer their customers universal connectivity at profitable prices below the large IBP's prices. In the scenario described in the example above, market forces, responding to a price increase by a large network, re-route network traffic so that it is served by rival networks, except for the traffic to and from the ISPs connected exclusively with the large network. The rivals purchase the remaining share from the large IBP in order to provide universal connectivity. Thus, the rivals' blended cost would permit them to profitably offer all transport at prices lower than the large IBP's prices, but above cost.

A direct effect of the increase in price by the large network is that: (i) ISPs who were originally exclusive customers of the large IBP would shift a substantial portion of their transit business to competitors; and (ii) ISPs that were not exclusive customers of the large IBP would also shift a significant share of their transit business to competitors' networks, keeping the connection with the large IBP only for traffic for which alternate routes do not exist or for cases of temporary failure of the rivals' networks.

Figure 2: Traffic flows between ISPs and a backbone



Similarly, degradation of interconnection to all backbones or sequentially one at a time is likely to be unprofitable. Degradation of interconnection to all backbones is clearly dominated by a price increase (since a price increase directly produces additional revenue to the firm while interconnection degradation does not directly increase revenue), and as we have shown earlier, competitive conditions severely limit price increases. Targeted degradation is also unprofitable for a large network that would initiate it because:

(i) ISP clients of the targeted network are likely to switch to third IBP networks that are unaffected by the degradation; it is very unlikely that any will switch to the degrading IBP network because it is itself degraded and cannot offer universal connectivity; there is no demand reward to the large IBP network;

(ii) Degradation of interconnection hurts all the ISP customers of the targeting IBP network as well, since they lose universal connectivity; these customers of the large network would now be willing to pay less to the large network; this leads to significant revenue and profit loss;

(iii) After losing universal connectivity, customers of the large IBP network are likely to switch to other networks that are unaffected by degradation and can provide universal connectivity; this leads to even further revenue and profit loss for the degrading network;

(iv) Multihoming ISPs would purchase less capacity from the large IBP network, or even terminate their relationship with the large network, which, through its own actions sabotages their demand for universal connectivity; this further reduces demand and profits for the degrading network; the same argument applies to multihoming customers of ISPs

(v) As the large IBP network pursues target after target, its customers face continuous quality degradation while the target's customers face only temporary degradation; this would result in further customer and profit losses for the large IBP network;

(vi) Prospective victims would seek alternative suppliers in advance of being targeted by the large IBP network; the scheme cannot play out the way it is proposed;

(vii) The degradation scheme is implausible in its implementation. How large do networks need to be to become serial killers? Why have we not observed this behavior at all?

(viii) There is no enduring change to the number of competitors in a market caused by serial degradation in a market with negligible entry barriers; the eliminated rival is likely to be replaced by another.

In conclusion, competition on the Internet backbone is strong with many carriers and easy entry and thus presently there are no significant competition concerns for Internet backbone services. However, local broadband access is typically a duopoly or monopoly depending on location. Local access networks are presently (in 2006) proposing to abolish the regime of net neutrality and impose fees to content and applications providers. The legality of this proposed change is questionable and imposition of such price discrimination may have adverse consequences on consumers' total surplus.

4. References

Bradner, Scott, (1999), *The Internet Standards Process*, revision 3, Network Working Group at ftp://ftp.isi.edu/in-notes/rfc2026.txt.

Cremer, Jacques, Patrick Rey, and Jean Tirole (2000), "Connectivity in the Commercial Internet" *Journal of Industrial Economics* vol. 48, pp. 433-472.

Cremer, Jacques, Patrick Rey, and Jean Tirole (1998), "The Degradation of Quality and the Domination of the Internet," Appendix 5 in the *Submission of GTE to the European Union for the merger of MCI with WorldCom*.

Economides, Nicholas (1996a), "The Economics of Networks," *International Journal of Industrial Organization*, vol. 14, no. 2, pp. 675-699, lead article. Pre-publication electronic copy available at http://www.stern.nyu.edu/networks/94-24.pdf .

Economides, Nicholas (2006a), "The Economics of the Internet Backbone," in *Handbook of Telecommunications*. Amsterdam: Elsevier Publishers (2006). Pre-publication electronic copy available at http://www.stern.nyu.edu/networks/ECONOMICS_OF_THE_INTERNET_BACKBONE.pdf

Economides, Nicholas (2006b), "Competition Policy in Network Industries: An Introduction," in Dennis Jansen (ed.), *The New Economy and Beyond: Past, Present and Future*, Edward Elgar (2006), pre-publication copy at http://www.stern.nyu.edu/networks/Economides_Competition_Policy.pdf.

European Union Commission (1998), *Statement of Objections to the MCI WorldCom Merger*.

Farrell, Joseph and Garth Saloner (1985), "Standardization, Compatibility, and Innovation," *Rand Journal of Economics*, vol. 16, pp. 70-83.

Kahn, Robert E. and Vinton G. Cerf (1999), "What Is The Internet (And What Makes It Work)," at http://www.wcom.com/about_the_company/cerfs_up/internet_history/whatIs.phtml.

Katz, Michael and Carl Shapiro, "Network Externalities, Competition and Compatibility," *American Economic Review*, vol. 75, no. 3 (1985), pp. 424-440.

Kende, Michael (2005a), Declaration of Michael Kende to the FCC in the Verizon-SBC merger**.**

Kende, Michael (2005b), Reply Declaration of Michael Kende to the FCC in the Verizon-SBC merger**.**

Liebowitz, Stanley J. and Stephen E. Margolis, "Network Externality: An Uncommon Tragedy," *The Journal of Economic Perspectives* (Spring 1994), pp. 133-150.

Milgrom, Paul, Bridger M. Mitchell and Padmanabhan Srinagesh, "Competitive Effects of Internet Peering Policies" in *The Internet Upheaval - Raising Questions, Seeking Answers in Communications Policy* [Edited by I. Vogelsang and B.M. Compaine], Cambridge, Mass., and London: MIT Press, 2000.

Schwartz, Marius (2005a), Declaration of Marius Schwartz to the FCC in the SBC-AT&T merger.

Schwartz, Marius (2005b), Reply Declaration of Marius Schwartz to the FCC in the SBC-AT&T merger.