NOTES ON INTERNET ECONOMICS AND MARKET STRUCTURE

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These notes provide a brief overview of the economic structure of the Internet. Just as our system of highways, roads, and bridges is the infrastructure that makes transportation and shipping possible, you can think of the Internet as the infrastructure that makes all of e-commerce possible. Thus if we want to understand the evolution of e-commerce, we must understand the basic economic structure of the Internet.

Our system of highways, roads, and bridges is almost entirely paid for by governments (federal, state, and local). If highways become overly congested and bridges start to collapse, transportation and shipping will suffer, and so will economic growth. We would then blame the government, which might or might not respond by investing more money in infrastructure improvements. Hopefully, government policy-makers would understand that this infrastructure is crucial to our economic well-being, and would act accordingly.

Although the Internet began as government-funded infrastructure (think of DARPA-net and the NSF-net, starting in the late 1960s), by the time personal computers became ubiquitous, the development of the Internet had become almost entirely private (at least in the U.S.). Thus the maintenance and expansion of this crucial infrastructure is in the hands of private profit-oriented companies. It is these companies that must invest in the cables, routers, switches, and related hardware and software needed to keep the Internet functioning. But these companies will make the necessary sunk cost investments only if they have an economic incentive to do so, and as we will see, that economic incentive is becoming less and less clear.

Figure 1 shows the backbone of the NSF-net as of 1988, or rather the part of the NSF-net that was in the U.S. Remember that 1988 was about seven years before the development of the World Wide Web and the introduction of commercial browsers (such as Netscape). It was a time of very limited Internet usage – mostly emails and data transfers among academics and research centers. Contrast this with the commercial backbones that developed shortly afterwards. Figures 2 and 3 show two examples – IBM's network ("Advantis") and GridNet, another commercial backbone.

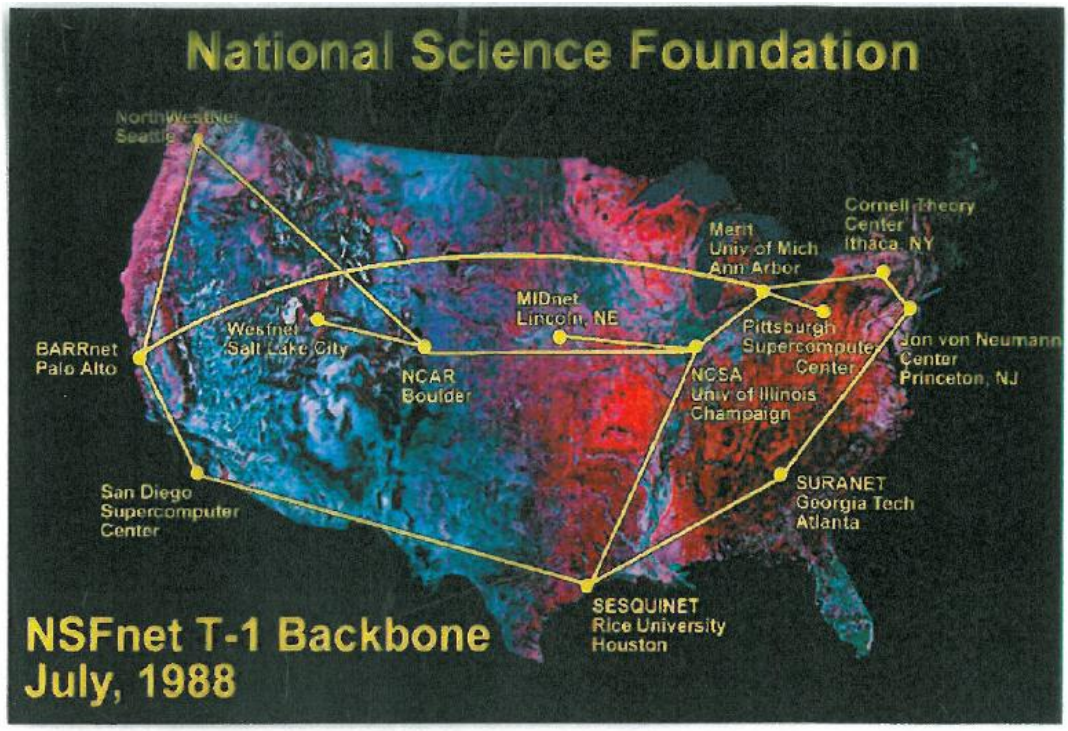


FIGURE 1: The NSF-net in 1988 (in the U.S.)

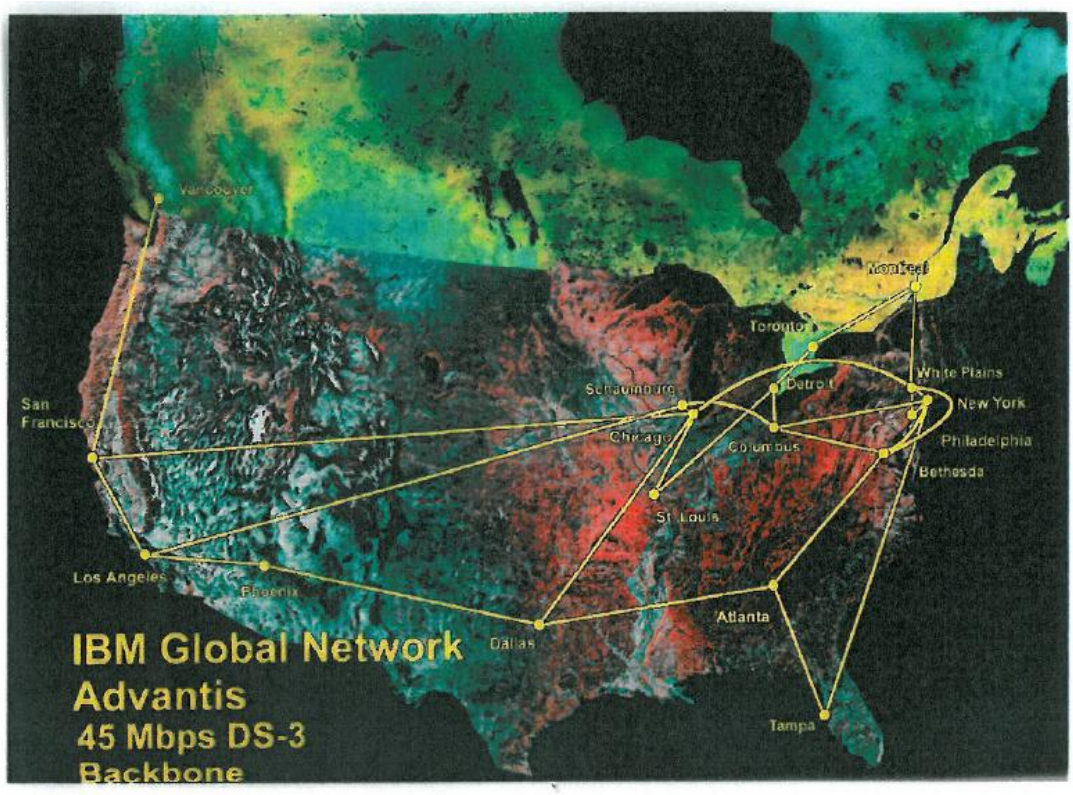


FIGURE 2: IBM's Backbone (in the U.S.)

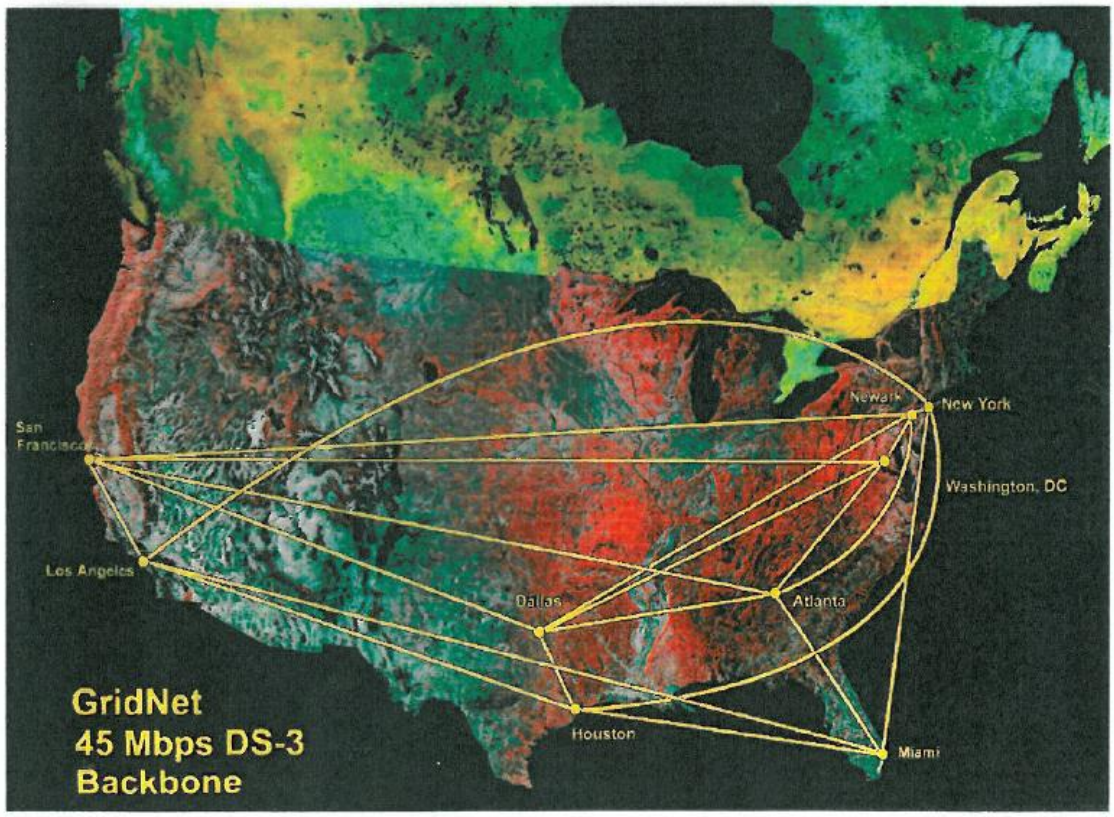


FIGURE 3: GridNet (in the U.S.)

The economic structure of the Internet is best understood in terms of three groups of players: consumers, Internet service providers (ISPs), and Internet backbone providers (IBPs), which provide high-bandwidth transmission, routing, and interconnections to ISPs and web-hosting services. Our focus will be on the Internet backbone providers; the backbone is equivalent to the Interstate Highway System in terms of infrastructure. We will be concerned with the flow of money from consumers to ISPs and IBPs; unless IBPs receive sufficient revenues, we cannot expect them to continue making sunk cost investments. We will see how IBPs compete, and how the prices they can charge are determined.

1. Internet Connectivity.

If you get in your car and start driving west, you know that you can eventually reach almost any city or town in the U.S. That's because the Interstate Highway System, along with our systems of state and local roads and bridges, provides complete connectivity. Likewise with the Internet. Consumers using the Internet expect *ubiquitous connectivity*: by entering an address (a URL in the case of the Web), you can connect to a computer or server almost anywhere in the world.

If you decide to drive from Boston to San Francisco, you know in advance that the highway system will provide the connectivity you need. Just use Google Maps or a GPS device to get the best routing. Of course on the way to San Francisco your car might break down or you might be delayed by a snowstorm. If something like that happens, you would probably take it in stride – that's just how it is when you go on a long road trip. But when it comes to the Internet, most people would find a "breakdown," even if it only causes a delay of an hour, to be completely unacceptable. Not only do we expect the Internet to give us ubiquitous connectivity, but we expect that connectivity to be nearly instantaneous, and to work virtually all the time. If it took 5 minutes for you to connect to a web site (e.g., Amazon or CNN), you would think that something is very, very wrong. You would think something is wrong because that connection usually takes only a few seconds.

If you think about it, accessing a web site half way around the world in a few seconds is quite amazing. When you type in a web address and hit "Enter," quite a bit happens that you are probably unaware of. To get an idea of what happens, look at Figure 4, which shows an actual Internet transmission from an individual in San Jose to an athletic association web site in Cape Town. Note that it took 25 "hops" to reach the target URL (www.athletics.org.za). At each "hop," data was transferred from one node to another, and three IBPs were involved: ConXion handed the data off to Level 3 at hop 6, Level 3 handed the data off to UUNET at hop 9, and then in South Africa UUNET handed the data off to a local ISP at hop 21.

Now look at the analysis at the top of the report: "But, problems starting at hop 17 in network 'UUNET SA 196-30-0-0-1' are causing IP packets to be dropped." Good grief! It seems that the data encountered a snowstorm, or the Internet equivalent, and packets were dropped. No need to worry. The Internet is built to handle exactly these kinds of problems. The information that was sent to Cape Town had been broken up into "packets," which would be reassembled once delivery was complete. Some of those packets are duplicative and redundant, so that the message can be reassembled even if some packets are lost. What's more, missing packets can be re-transmitted if necessary (which is rare).

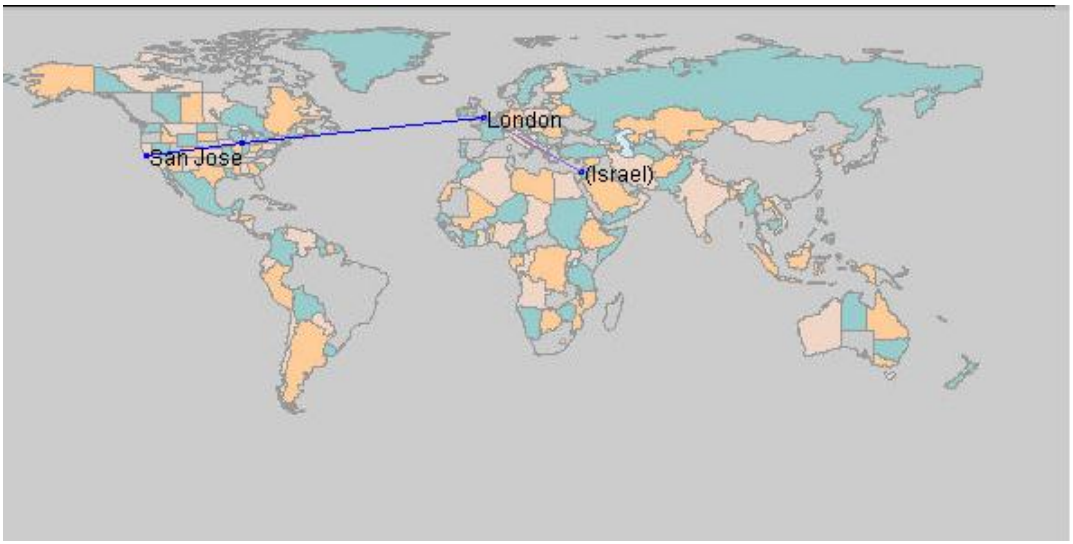
Figure 5 shows another example, in this case a transmission from an individual in San Jose to a newspaper web site in Tel Aviv. In this case it took 19 hops to reach the target URL (www.haaretz.co.il). Once again, several IBPs had to cooperate by forwarding each other's data. And once again, the data encountered a minor snowstorm; as the analysis states: "But, problems starting at hop 9 in network 'Level 3 Communications, Inc. LEVEL-3-CIDR' are causing IP packets to be dropped." And as before, redundancy allowed the message to be completely reassembled at its destination. And finally, *all of this took about 2 seconds*. Quite amazing!

Report for www.athletics.org.za [196.2.137.50]

Analysis: 'www.athletics.org.za' [cluster.supersport.co.za] was found in 25 hops (TTL=103). But, problems starting at hop 17 in network "UUNET SA 196-30-0-0-1" are causing IP packets to be dropped.

Hop	IP Address	Node Name	Location	Tzone	ms	Network
1	Security Check	Security Check	...		0	ConXioN Corporation CON
2	Security Check	Security Check	...		0	ConXioN Corporation CON
3	private	private	...		0	ConXioN Corporation CON
4	private	private	...		0	ConXioN Corporation CON
5	private	private	...		0	ConXioN Corporation CON
6	65.57.244.13	ge-1-1.hsa3.San.	San Jose, CA, USA	-08:00	0	Level 3 Communications,
7	4.68.114.153	so-2-1-0.bbr1.Sai	San Jose, CA, USA	-08:00	0	Level 3 Communications,
8	209.244.3.138	so-6-0-0.edge1.S	San Jose, CA, USA	-08:00	0	Level 3 Communications,
9	204.255.173.41	0.so-1-1-0.BR1.S	Santa Clara, CA, USA	-08:00	0	UUNET Technologies, Inc
10	152.63.57.50	0.so-0-2-0.XL2.S(	Santa Clara, CA, USA	-08:00	0	UUNET Technologies, Inc
11	152.63.48.93	0.so-3-0-0.TL2.S(	Santa Clara, CA, USA	-08:00	0	UUNET Technologies, Inc
12	152.63.101.49	0.so-4-0-0.TL2.AT	Atlanta, GA, USA	-05:00	62	UUNET Technologies, Inc
13	152.63.86.186	0.so-4-1-0.XL2.MI	Miami, FL, USA		78	UUNET Technologies, Inc
14	152.63.101.45	0.so-3-0-0.XR2.M	Miami, FL, USA		78	UUNET Technologies, Inc
15	152.63.7.181	206.ATM4-0.IH4.M	Miami, FL, USA		78	UUNET Technologies, Inc
16	152.63.86.146	POS2-0-0.IR2.MIA	Miami, FL, USA		87	UUNET Technologies, Inc
17	196.30.229.173	atm5-0-0sub200.	Miami, FL, USA		197	UUNET SA 196-30-0-0-1
18	196.30.229.158	pos1-0-0.cr1.mia	Miami, FL, USA		209	UUNET SA 196-30-0-0-1
19	196.30.200.10	fe0-0.gw2.jnb2.al	-		425	UUNET SA 196-30-0-0-1
20	196.31.216.250	mweb-jnb2-1.cus	-		421	UUNET SA 196-31-0-0-1
21	196.2.146.2	vic3725-core.mw	Cape Town, South Afr	+02:00	422	M-WEB MWEB-2BLK
22	196.2.146.21	fwdx.mweb.net	Cape Town, South Afr	+02:00	418	M-WEB MWEB-2BLK
23	196.2.146.134	3550l3-core.sw2.	Cape Town, South Afr	+02:00	429	M-WEB MWEB-2BLK
24	196.2.146.149	viking1.mweb.net	Cape Town, South Afr	+02:00	420	M-WEB MWEB-2BLK
25	196.2.137.50	www.athletics.org	Cape Town, South Afr	+02:00	421	M-WEB MWEB-2BLK

FIGURE 4: Internet transmission from Palo Alto to Cape Town



Report for www.haaretz.co.il [212.150.63.115]

Analysis: 'www.haaretz.co.il' was found in 19 hops (TTL=234). But, problems starting at hop 9 in network "Level 3 Communications, Inc. LEVEL3-CIDR" are causing IP packets to be dropped.

Hop	IP Address	Node Name	Location	Tzone	ms	Network
1	Security Check	Security Check	...		0	ConXioN Corporation CON
2	Security Check	Security Check	...		0	ConXioN Corporation CON
3	private	private	...		0	ConXioN Corporation CON
4	private	private	...		0	ConXioN Corporation CON
5	private	private	...		0	ConXioN Corporation CON
6	65.57.244.13	ge-1-1.hsa3.San.	San Jose, CA, USA	-08:00	0	Level 3 Communications,
7	4.68.121.233	so-2-3-0.bbr2.Sa	San Jose, CA, USA	-08:00	0	Level 3 Communications,
8	64.159.1.37	so-2-3-0.bbr2.Ch	Chicago, IL, USA	-06:00	47	Level 3 Communications,
9	209.244.8.14	so-7-0-0.edge1.C	Chicago, IL, USA	-06:00	46	Level 3 Communications,
10	209.0.227.74	telia-level3-ge.Ch	Chicago, IL, USA	-06:00	47	Level 3 Communications,
11	213.248.80.74	nyk-bb2-pos7-1-0	-		78	Telia International Carrier
12	213.248.65.93	ldn-bb2-pos6-0-0	London, UK	*	140	Telia International Carrier
13	213.248.64.213	ldn-bb1-pos7-3-0	London, UK	*	140	Telia International Carrier
14	213.248.74.2	ldn-b2-pos9-0.tel	London, UK	*	140	Telia International Carrier
15	213.248.100.26	barak-100689-ldr	London, UK	*	140	Telia International Carrier
16	212.150.232.249	-	(Israel)	+02:00	227	BarakNet
17	212.150.232.126	-	(Israel)	+02:00	225	BarakNet
18	206.49.94.116	barak-1-acc-3.ba	(Israel)	+02:00	247	BARAK BARAK-BLK-1
19	212.150.63.115	www.haaretz.co.il	(Israel)	+02:00	218	Barak WAN Connection

FIGURE 5: Internet Transmission from Palo Alto to Tel Aviv

The need for ubiquitous connectivity creates network externalities, and creates strategic problems for IBPs. Each IBP has an installed base of customers but competes for unattached customers. At issue is compatibility with other IBPs: *quality of interconnection* is a strategic variable. When the connectivity between two IBPs is degraded, both IBPs face a demand

reduction, because customers' access to each other deteriorates. On the other hand, reduced connectivity also creates quality differentiation between IBPs: the larger IBP, which relies less on access to the other IBP's customers, gains a competitive advantage. This in turn creates the potential for market power in the "IBP market," and reduced connectivity.

To understand how the Internet provides connectivity, keep in mind its hierarchical structure: IBPs on top, ISPs in the middle, and customers at the bottom. This is illustrated in Figure 6, which might apply in the 1990s or the year 2000. In this figure, most consumers access the Internet via an ISP. In the 1990s, there were thousands of ISPs in the U.S. alone. The majority of them provided service via relatively slow telephone modem connections. These ISPs would connect with an IBP; you the consumer would send data to your ISP, who would "forward" it to the IBP with which it has contracted. What is essential here is that IBPs "peer" with each other: they agree to route all traffic destined to their own customers, to customers of their customers, etc. For example, in the case of the transmission from San Jose to Cape Town illustrated in Figure 4, ConXion peered with Level 3, which peered with UUNET. Without those peering agreements, the transmission could not have reached the target URL in Cape Town.

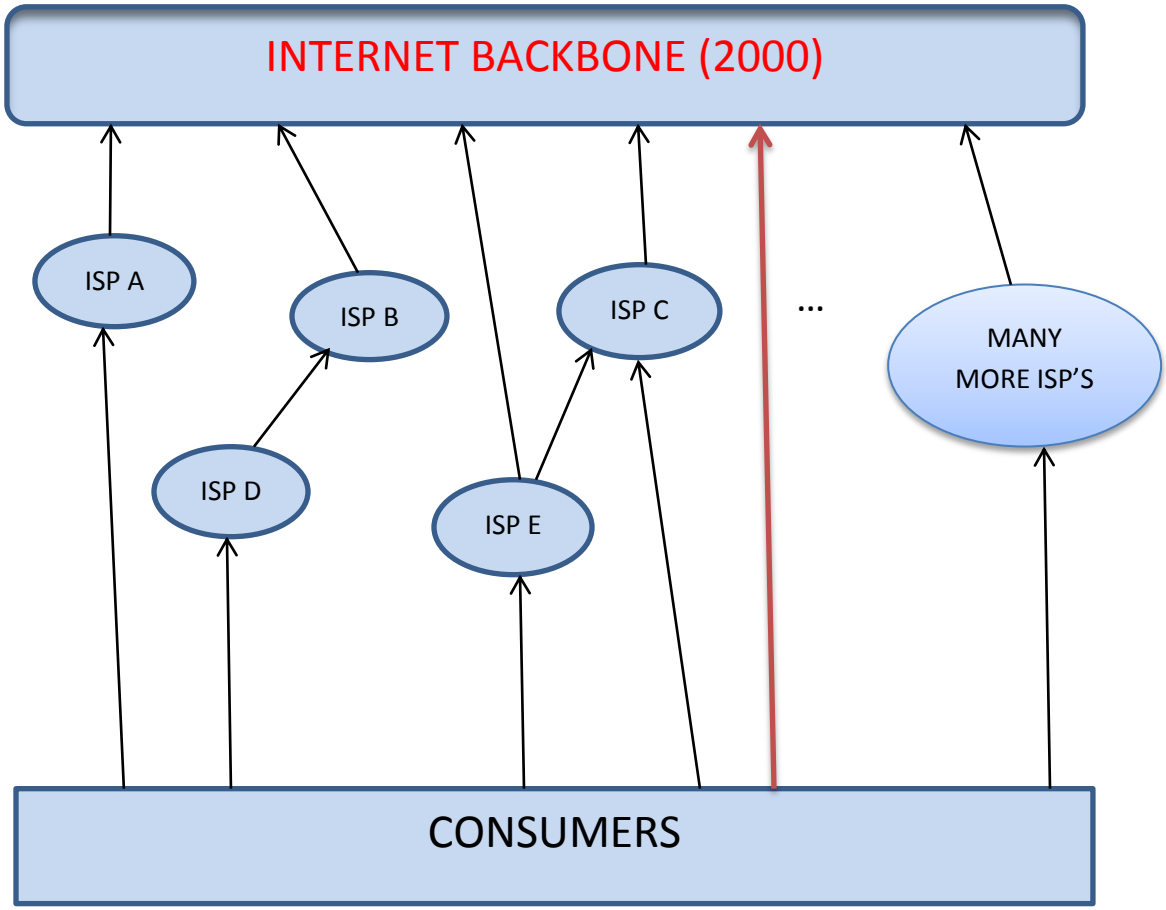


FIGURE 6: INTERNET STRUCTURE IN THE YEAR 2000

Because of limited capacity at the public peering points that were established years ago, IBPs developed private peering arrangements (exchanging traffic pair-wise at bilateral interfaces). However, IBPs obtain limited revenue from these peering relationships. IBPs charge their customers, who charge their customers, who charge their own customers. In Figure 6, money flows from the bottom (customers) to the top (IBPs). The problem for IBPs is that they have very large sunk costs, and very low marginal costs. In addition, they sell a homogenous product. The result is that it is difficult or impossible for IBPs to recover their sunk costs. (This is called the "sunk cost/marginal cost dilemma.")

Figure 7 shows the Internet in 2012. The main difference from Figure 6 is that there are many fewer ISPs, and some are quite large (e.g., ISP B in the figure). The provision of Internet service has become much more concentrated in most parts of the country, as we have moved to high-speed cable and DSL connections. If you live in the Boston area, the odds are that your ISP is either Comcast or Verizon. But the smaller number of ISPs means that they have monopsony power as buyers of backbone service. This puts further pressure on the backbone providers, pushing down their prices for service.

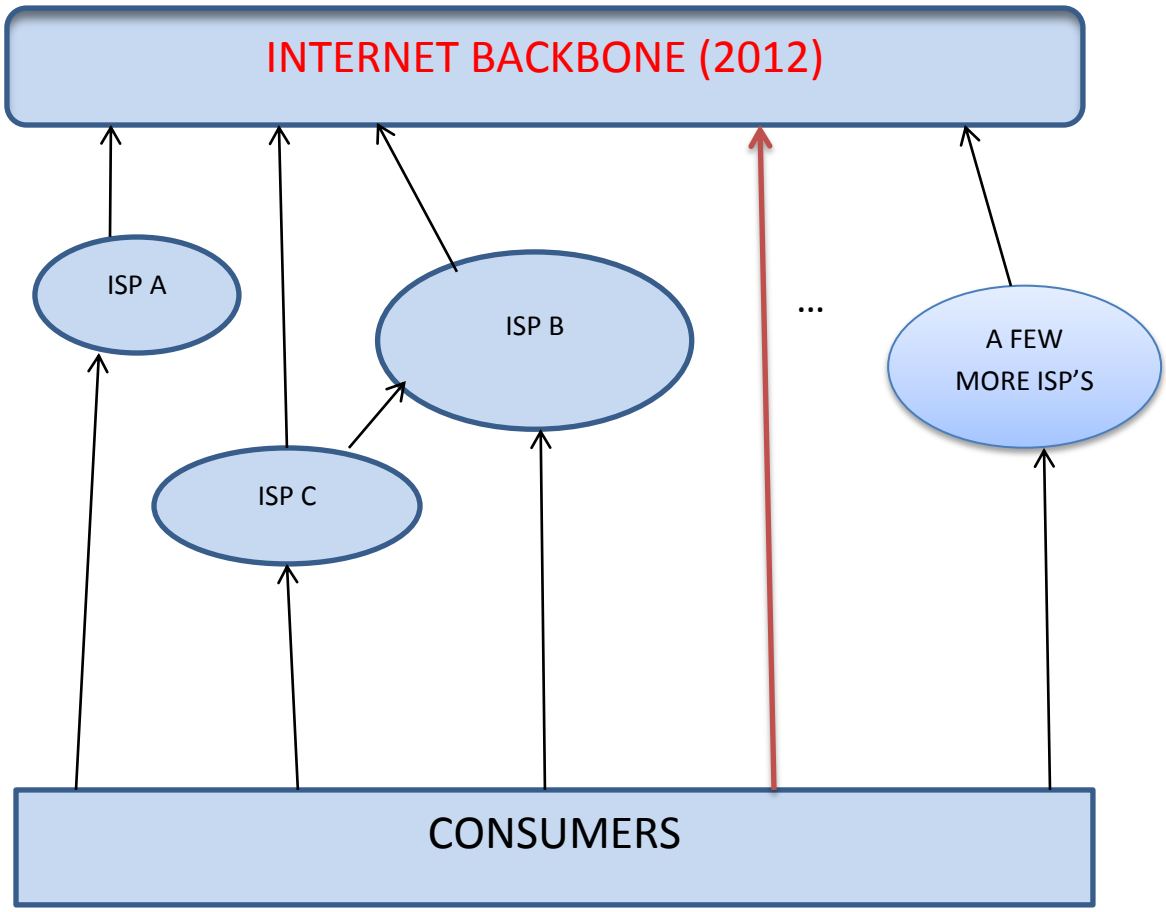


FIGURE 2: INTERNET STRUCTURE IN THE YEAR 2012

2. Threats to Connectivity.

The Internet developed in a haphazard way, with most of the private peering arrangements based on "good will," and a sense during the 1990s that everything will work out, and everyone will make money as the use of the Internet explodes. The use of the Internet has indeed exploded, but it is not clear any more that everything will work out. The backbone companies must now think carefully about their incentives to interconnect. In particular, should an IBP agree to peer with all other IBPs? Should the quality of its peering be the same, regardless of with whom it is peering?

Interconnection involves different dimensions of quality. Of these, delay is probably the most important. Delays can occur via transmission rates, and via queues at switches (routers). For example, the incoming rate at a router can exceed the outgoing rate, so that a queue builds up. In that case, "packets" at the end of the queue are likely to be delayed, thereby delaying the entire message of which the packets are a part (even a small part).

Currently, interconnection agreements are based on a "best effort" model, but this model may break down in the future, as Internet traffic grows. One might argue that perhaps the Internet should be regulated. For example, perhaps the Federal Communications Commission (FCC) should regulate interconnection agreements, and require specific levels of quality. It is hard to imagine, however, how this could work. The FCC cannot force backbone providers to invest more money in routers, but without more and better routers, interconnection quality will necessarily drop. Furthermore, for the FCC, the trend has been away from regulation. For example, the 1996 U.S. Telecommunications Act states that the Internet should be "unfettered by Federal or state regulation."

2.1 Might Peering Quality Be Reduced?

The problem now is that IBPs cannot cover their sunk costs, and thus have a reduced incentive (to put it mildly) to continue to make sunk cost investments in routers, etc. In fact, some of the larger IBPs might have an incentive to purposely reduce the quality of some of their interconnections in the hope of thereby gaining dominance.

This comes back to the network externality – if interconnection quality is poor, you as a customer will prefer to contract with the largest IBP, because that way *you will minimize the expected number of interconnections*. If more and more customers move to the largest IBPs, those large IBPs will grow at the expense of the smaller ones, and the market will become more concentrated. A more concentrated market will, in turn, reduce competition by making coordinated pricing easier. This, large IBPs might find that "targeted degradation" of peering is profitable in the long run.

What could ISPs and other large customers do in response to the degradation of peering quality? For some of the largest ISPs, the response might be to "multihome," i.e., become customers of several IBPs. But this is costly. First, it is then necessary to pay two or more IBPs for service instead of one. Second, there will be a loss of scale economies; splitting traffic among two or more IBPs increases the total connection cost. Furthermore, even if an ISP could protect itself from a degradation of connectivity, there is still the fact that a dominant IBP may be able to raise prices.

Questions: Currently there are 4 or 5 large IBPs, and many smaller ones. (See the table at the end.) Should we expect the market to become more concentrated? Can we rely on the antitrust laws to prevent reduced connectivity and the emergence of a dominant player?

Level 3/Global Crossing: On April 11, 2011, Level 3 (the largest IBP) announced its intention to buy Global Crossing (the third largest) in a deal worth about $3 billion. According to NYT, "The deal would combine the two companies' fiber-optic networks over three continents, offering data and voice connections to more than 70 countries. The combined entity will create a company with revenue of $6.26 billion and earnings of $1.57 billion, after taking into account projected cost savings." The merger was approved in September 2011, and closed on October 4, 2011. Earnings of $1.57 billion would be quite an accomplishment – at the time of the merger, both companies had been losing substantial amounts of money on their backbone activities. Would the new company have sufficient scale to increase prices?

Update: Level 3 has continued to lose money. In Q1 2012 it lost $0.37 per share, and in Q2 2012 it lost $0.29 per share. As one analyst put it (at Seeking Alpha, on 7/26/2012), "Even more amazing is that the company has a market cap of $4B."

2.2 Do We Need a Different Pricing Model?

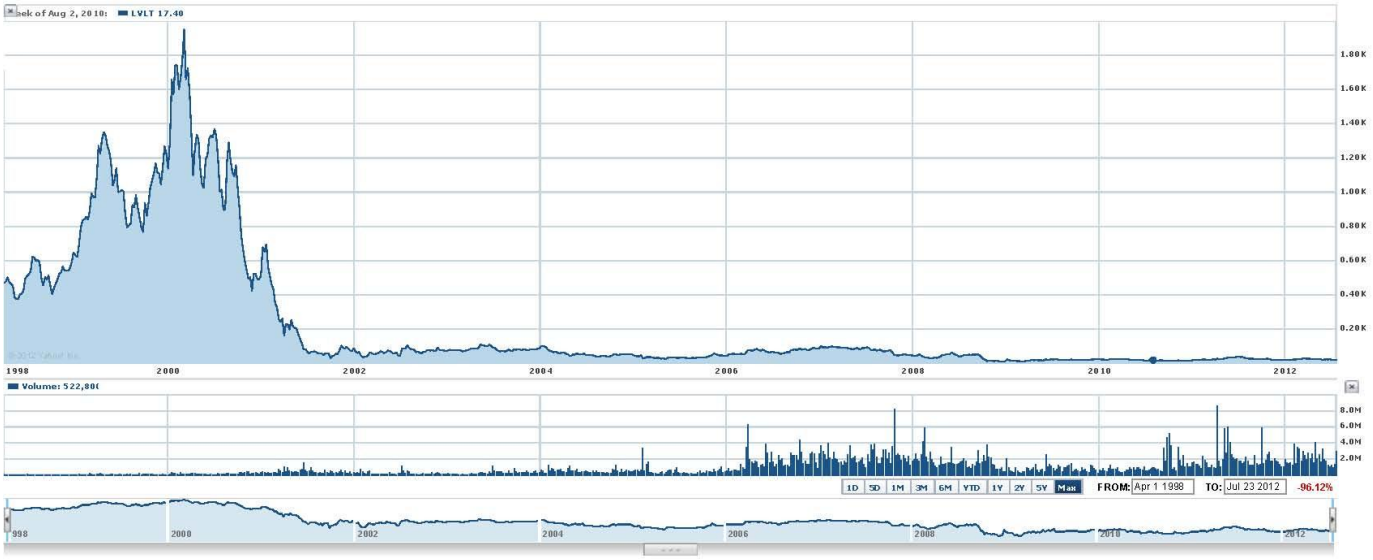
As we have seen, IBPs face a "sunk cost/marginal cost dilemma." Sunk costs are large, and marginal costs are close to zero. Unless you have a preference for the electrons (and in the case of fiber optic cable, photons) of Level 3 over Cogent or ATT, you will choose to contract with the IBP that provides the best pricing. Thus prices are driven down, and long-run profitability becomes problematical. (Look at the financial performance and stock price of Level 3, now merged with Global Crossing, to see this happening.)

Lower prices are, of course, good for consumers. But lower quality is not. If the result is that IBPs start to reduce their capital investments (either through "targeted degradation" or simply untargeted degradation of connection quality), the Internet will slow down. If the interstate highways (e.g., routes I-90, I-91, and I-95) become filled with potholes, collapsing bridges, etc., it will take longer to drive from Boston to New York. Maintaining the quality of

our highways is the job of the government, but it is not the government's job (at least not so far) to maintain the quality of our Internet infrastructure.

It may be that what is needed is a different pricing model for the transmission of information by IBPs (and ISPs). Indeed, this is what the debate about "network neutrality" is all about – whether providers should be able to charge different prices for different speeds of transmission, or for different types of content.

Questions: Should the FCC enforce "network neutrality?" Should Google and Verizon be able to sign an agreement by which Verizon will charge different prices for different kinds of content transmitted over their network?



LEVEL 3 COMMUNICATIONS – STOCK PRICE

TOP INTERNET BACKBONE PROVIDERS IN 2010
(Ranked by Knodes Index)

Rank	Provider	Knodes Index* (Internet Hops)	Peers
1	Level 3 Communications	1.75	2,703
2	Cogent Communications	1.84	2,696
3	Global Crossing	1.85	1,390
4	Sprint	1.86	1,316
5	Tiscali Intl. Network	1.88	664
6	NTT America	1.88	588
7	AT&T WorldNet	1.88	2,332
8	Swisscom Ltd.	1.92	548
9	Hurricane Electric	1.92	1,385
10	TeliaNet Global Network	1.93	568

***Knodes Index combines relative size, IP address control, and peering arrangements. Indicates averages number of networks (hops) that must be traversed between any IP address on a given network to any other IP address on the Internet.**