

NOTES ON INTERNET ECONOMICS AND INTERNET MUSIC

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These notes provide a brief overview of the economic structure of the Internet, and an even briefer overview of the development of Internet music, beginning with the opening of Apple's iTunes store at the end of 2002. We will see how the Internet has become a crucial form of infrastructure, which raises complex questions regarding pricing and regulation. And needless to say, without the Internet there would be no Internet music.

1. 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.

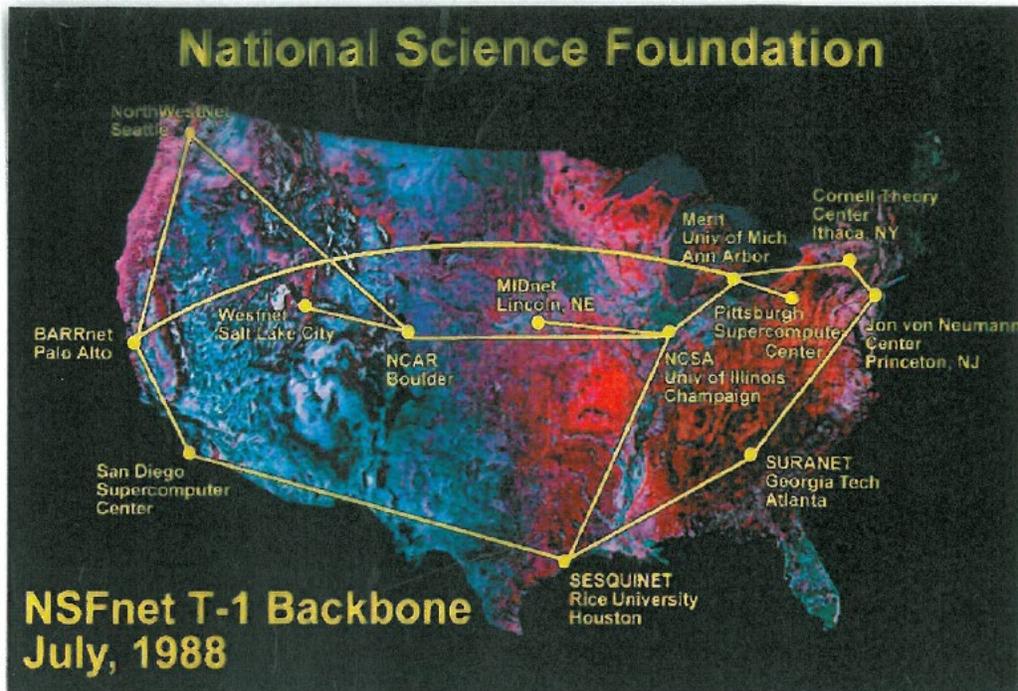


FIGURE 1: The NSF-net in 1988 (in the U.S.)

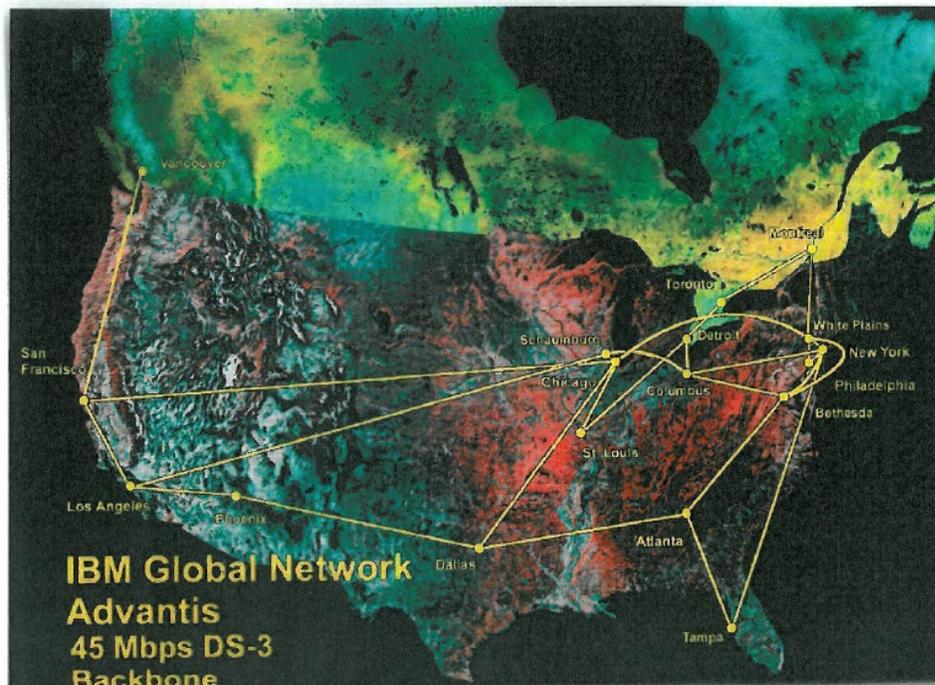


FIGURE 2: IBM’s Backbone (in the U.S.)

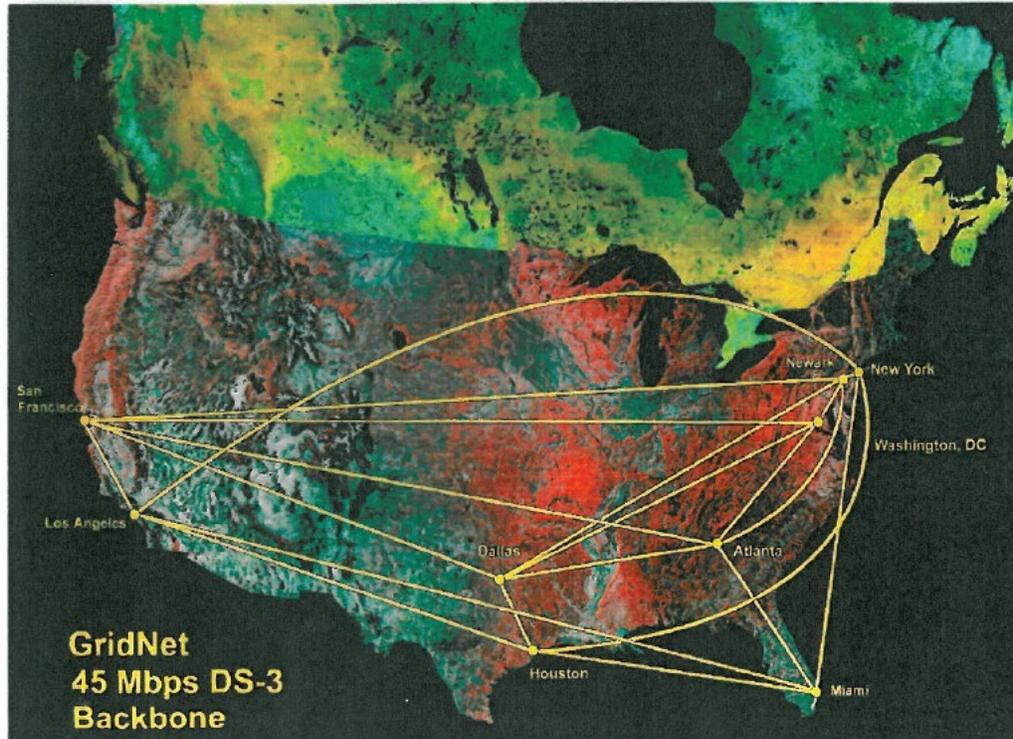


FIGURE 3: GridNet (in the U.S.)

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, and especially the “Tier 1” providers – the very large and global IBPs that “peer” with each other, i.e., that interconnect and transmit each other’s data at little or no cost. 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.

1.1. Internet Connectivity.

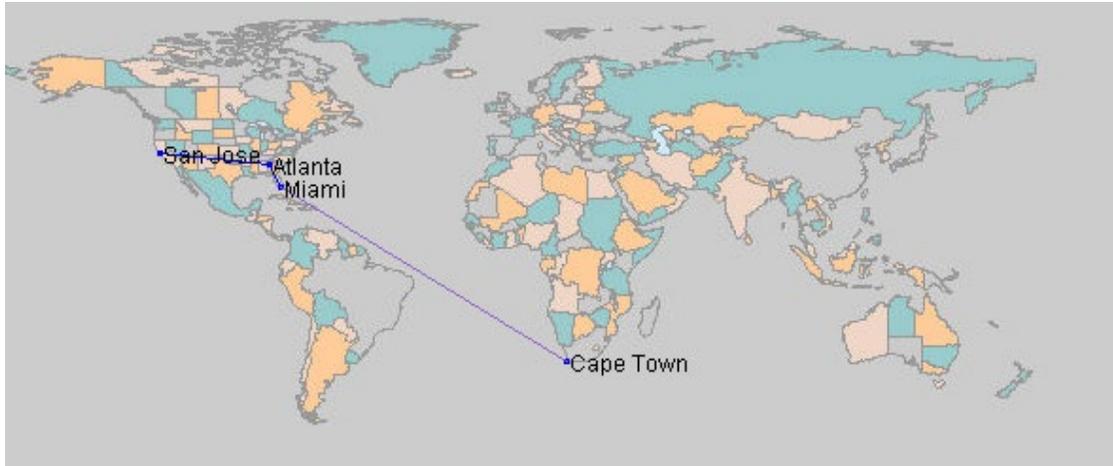
If you get in your car and start driving, you know that you can eventually reach almost any city or town in the U.S. That’s because the Interstate Highway System, along with our systems of state and local roads and bridges, provides complete connectivity. Likewise with the Internet. Consumers using the 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, or you might encounter some bad traffic jams. 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 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 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 COM
2	Security Check	Security Check	...		0	ConXioN Corporation COM
3	private	private	...		0	ConXioN Corporation COM
4	private	private	...		0	ConXioN Corporation COM
5	private	private	...		0	ConXioN Corporation COM
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.Sa	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.Sc	Santa Clara, CA, USA	-08:00	0	UUNET Technologies, Inc
11	152.63.48.93	0.so-3-0-0.TL2.Sc	Santa Clara, CA, USA	-08:00	0	UUNET Technologies, Inc
12	152.63.101.49	0.so-4-0-0.TL2.A	Atlanta, GA, USA	-05:00	62	UUNET Technologies, Inc
13	152.63.86.186	0.so-4-1-0.XL2.M	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.MI	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.af	-		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.mwi	Cape Town, South Afr	+02:00	422	M-WEB MWEB-2BLK
22	196.2.146.21	fdx.mweb.net	Cape Town, South Afr	+02:00	418	M-WEB MWEB-2BLK
23	196.2.146.134	3550I3-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 COF
2	Security Check	Security Check	...		0	ConXioN Corporation COF
3	private	private	...		0	ConXioN Corporation COF
4	private	private	...		0	ConXioN Corporation COF
5	private	private	...		0	ConXioN Corporation COF
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.Sai	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-C	-		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.bai	(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.

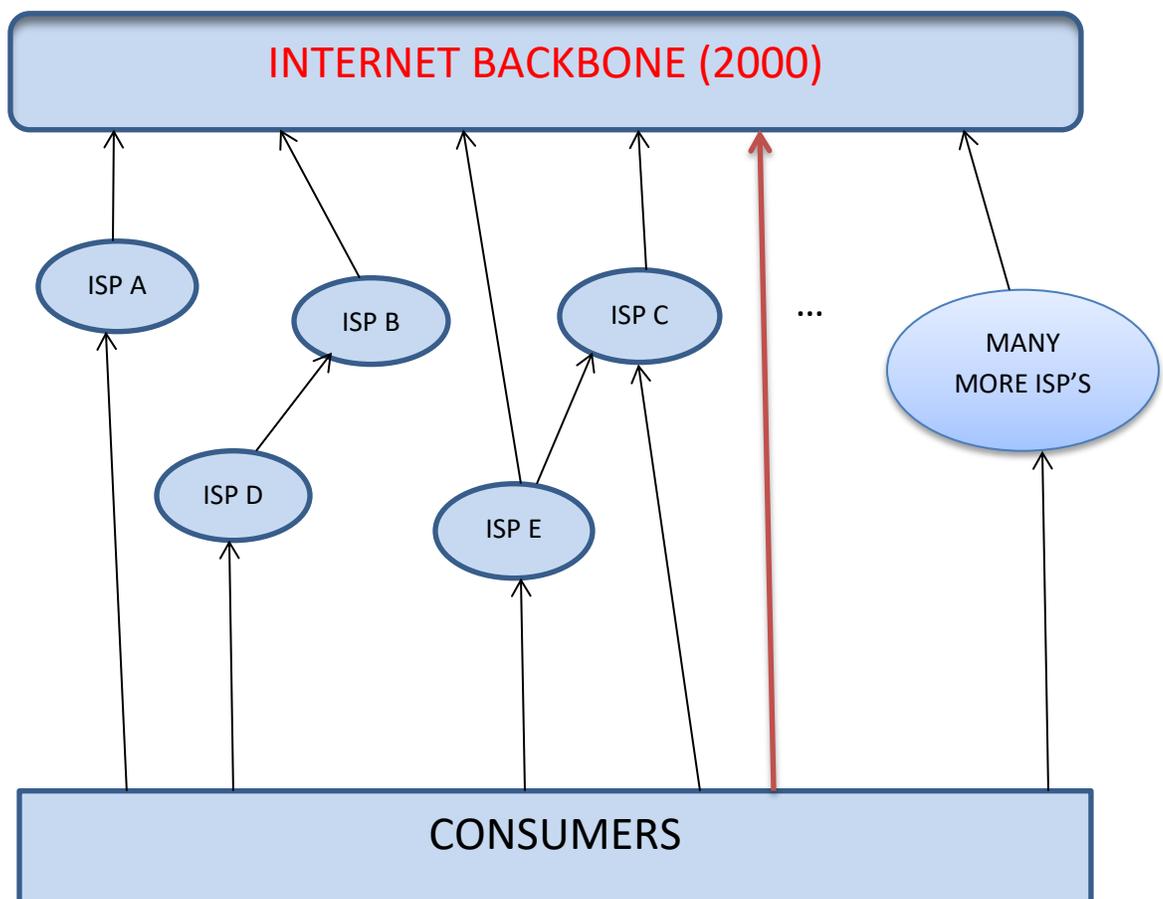


FIGURE 6: INTERNET STRUCTURE IN 2000

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 little or no 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.”)

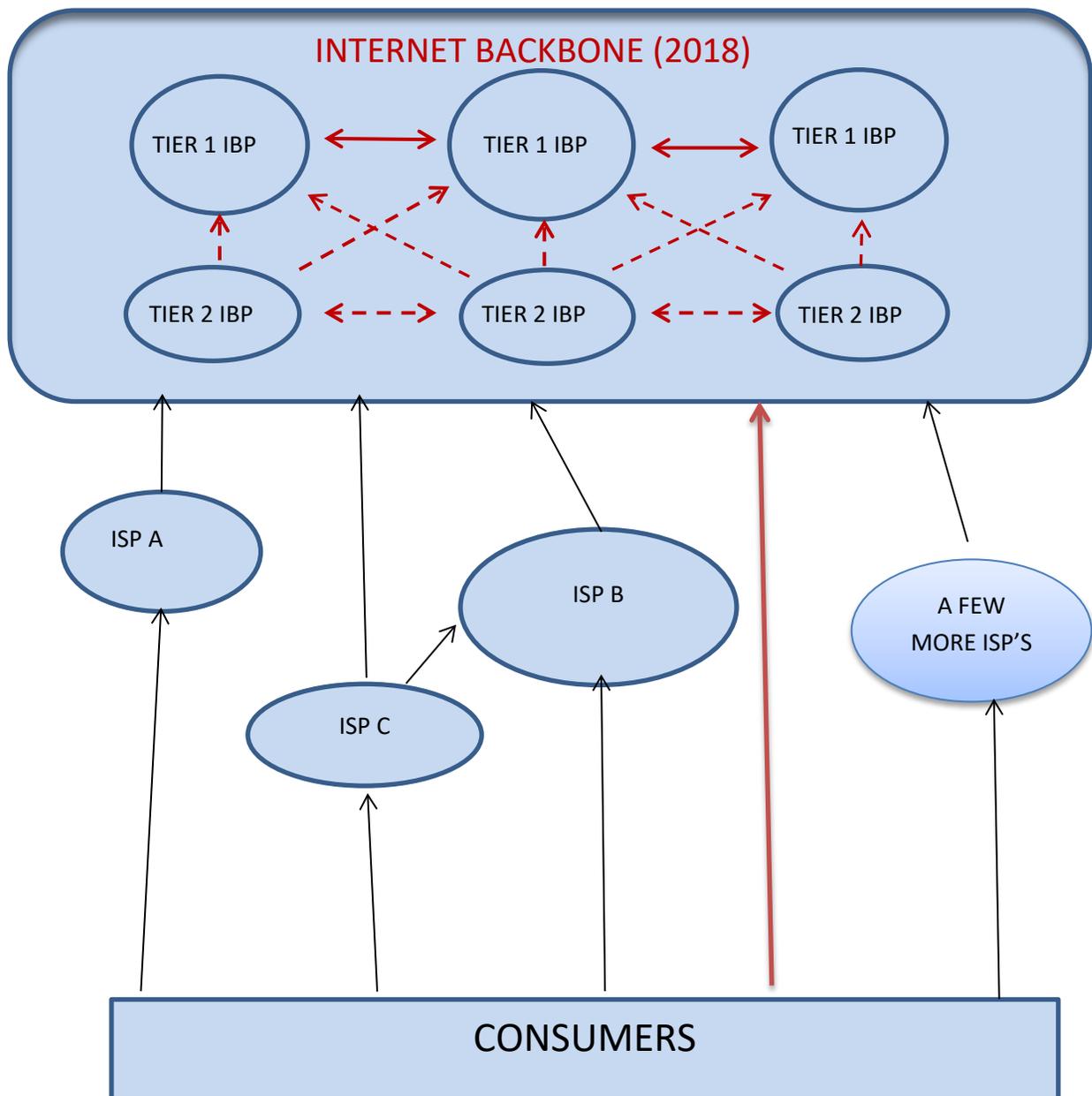


FIGURE 7: INTERNET STRUCTURE IN 2021

Figure 7 shows the Internet in 2018. Compared to Figure 6, there are two important differences. The first is that there are two classes of IBPs. The first, called “Tier 1,” consists of large global IBPs (such as Level 3 Communications). They peer with each other, which means they exchange each other’s traffic at no cost, as indicated by the solid red arrows. The second class, “Tier 2,” are smaller backbone providers. They have *transit arrangements* with each other and with the Tier 1 IBPs. “Transit” means (negotiated) fee-based peering, and is indicated by the dashed red arrows. (The larger ISPs are often called “Tier 3” providers; they have transit arrangements with each other and with the Tier 1 and Tier 2 providers.)

The second difference with Figure 6 is that today 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.

Finally, much of the Internet backbone is global, so that peering and transit arrangements must be negotiated internationally. (See Figure 8.) And often these arrangements involve agreements to connect *regional* backbone networks.

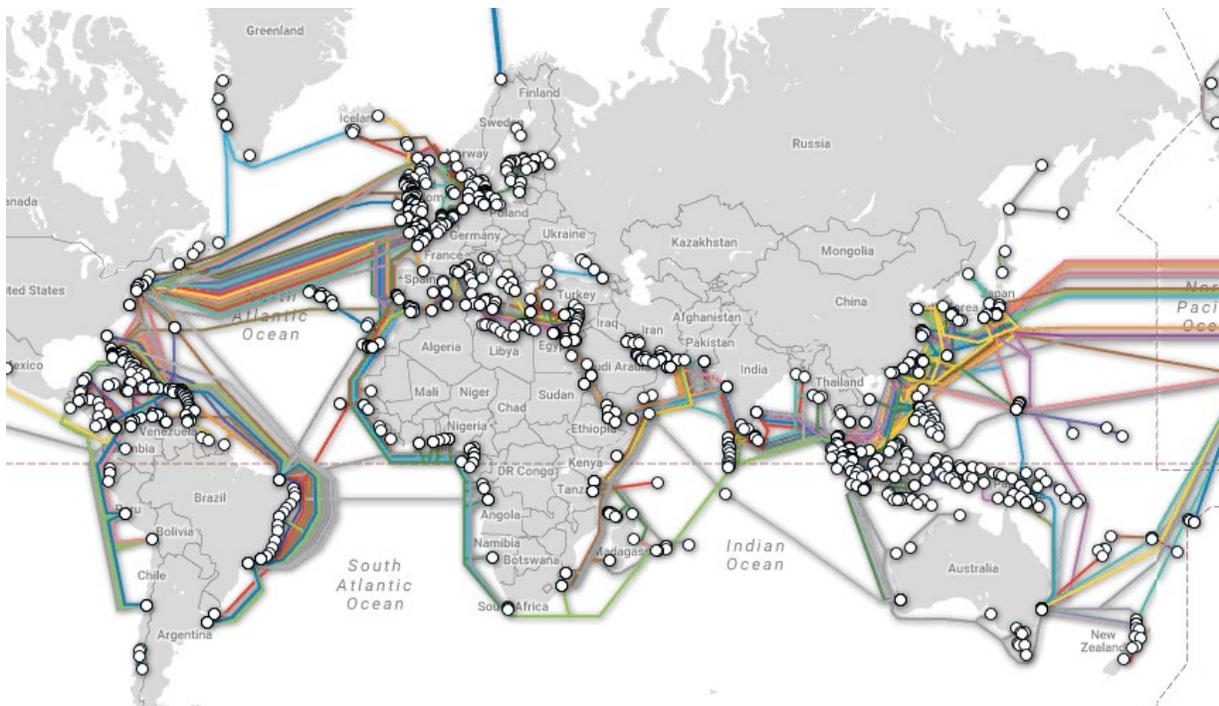


FIGURE 8: GLOBAL BACKBONE IN 2021.

1.2. 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.” Finally, much of the backbone exists outside the U.S., but must connect with the parts that are within the U.S.

1.2.1 The Sunk Cost – Marginal Cost Dilemma.

The problem faced by many IBPs is that they 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 (Tier 1) 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*. That is one reason that large businesses such as Netflix and Apple connect directly to Level 3, currently the largest IBP. 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 about a half dozen large IBPs, and many smaller ones (mostly Tier 2). 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? The Level 3 acquisition of Global Crossing – creating what is now by far the largest IBP (see below) – was approved quickly.

Level 3/Global Crossing: On April 11, 2011, Level 3 (at that time 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?

In the year or so following the merger, Level 3 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.” But by late 2013 it broke even, and began to earn profits in 2014. Its stock price jumped, and its market cap in July 2014 was about \$10 billion. Its position as by far the largest IBP has indeed enabled it to charge a price premium. And in June 2014, Level 3 acquired TW Telecom, a Tier 2 backbone provider. But by 2015, Level 3 was losing money again, and seeking another merger or buyout. In November 2017, Level 3 was acquired by CenturyLink for about \$25 billion.

Other Tier 1 IBPs have not had this size advantage, and profits have been elusive. But unless they continue to make large sunk cost investments, they will be at an increasing size disadvantage. The market will become less and less competitive.

1.2.2 Do We Need a Different Pricing Model?

As we have seen, most 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.

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.

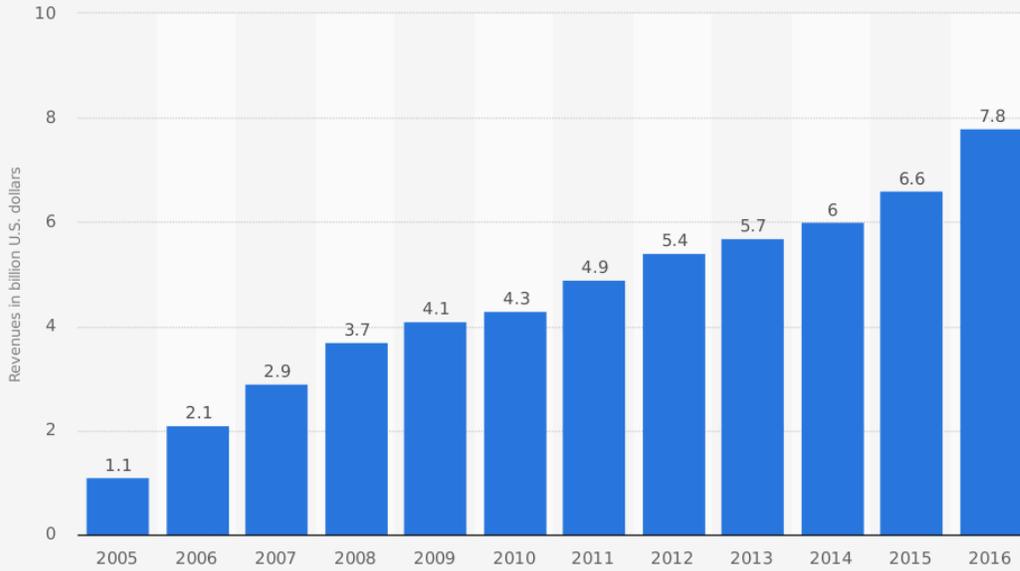
Questions: Should the FCC enforce “network neutrality?” Should Google and Verizon be able to sign an agreement by which Verizon will charge different prices for different kinds of content transmitted over their network? Netflix, for example, having experienced a sharp drop in primetime transmission rates on most ISPs in the past, would be happy to pay for increased bandwidth.

2. Internet Music.

Let’s put aside for now any economic problems related to the Internet backbone, and assume that the Internet will remain a well-functioning and efficient form of infrastructure, so that various forms of e-commerce can continue to thrive. Now we will turn to one specific area of e-commerce, namely Internet music.

Prior to 2003, there was no such thing as “Internet music.” Yes, music files were exchanged over the Internet, but those exchanges were casual and often illegal. In 2001 you might have been able to obtain some songs from a friend, but there was no straightforward way to *purchase* those songs. That changed with Apple’s launch of its iTunes store at the end of 2002, about a year or so after its launch of the iPod. (Prior to the iTunes store, you would put music on your iPod by copying – “ripping” – a CD to your computer, and then using the iTunes software to copy the songs to your iPod.)

Global digital music revenue from 2005 to 2016 (in billion U.S. dollars)

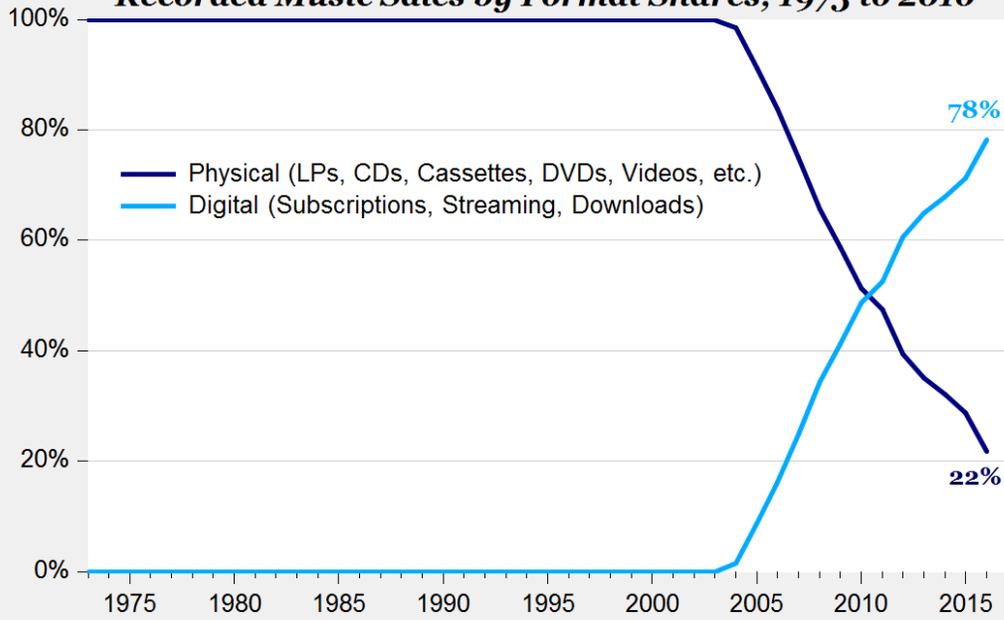


Source:
IFPI
© Statista 2017

Additional Information:
Worldwide; 2005 to 2016



Recorded Music Sales by Format Shares, 1973 to 2016



Source: Recording Industry Association of America

The iTunes store was premised on the idea that people would be willing to *pay* for music, rather than just obtain it from friends, perhaps illegally. It turned out that people were indeed willing to buy music, and the iTunes store proved to be a big success. Soon other companies (most notably Amazon and Google) started selling music, and generally matched Apple's prices. In later years consumers shifted from *buying* music to *renting* music via a plethora of streaming services (such as Spotify, but also Apple Music, Amazon Music, and several other services). Some consumers also turned to music *discovery*, as companies like Pandora provided curating services. As the figures on the previous page illustrate, the sale of cassettes and CDs declined rapidly over the past two decades, but digital music revenue took its place and grew steadily.

The evolution of Internet music raises a number of interesting questions. First, what are the relevant markets in which companies are competing? Going back to 2003 (well before streaming), was there a market for Internet music downloads that was distinct from a possible market for pre-recorded CDs? In more recent years, can we say that there is a distinct market for music library subscriptions (like Spotify), or a possible market for music discovery ("curating") services (like Pandora)? Who are the buyers and sellers in each of these possible markets?

We will look at Internet music from the point of view of Apple and its experience with iTunes, and later Apple Music, and from the more recent experience of Spotify. Beginning with the introduction of the iTunes store, Apple was clearly the dominant seller of Internet music downloads. Furthermore, iTunes music downloads supported – and was supported by – sales of iPods, and both iTunes and iPods were crucial driving forces for Apple's growth. In 2005, for example, iPod sales were about \$4.5 billion and iTunes sales about \$900 million, which together accounted for 39% of Apple's total revenue. Putting aside the iPhone, in 2012 iPod and iTunes sales were \$5.6 billion and \$7.5 billion respectively, accounting for about 8% of total revenue. The iTunes store has accounted for a steady 70% or more of (legal) Internet music downloads.

Apple has faced a variety of strategic issues in connection with the iPod, iTunes, and Apple Music. Originally, music from the iTunes store could only be played on an iPod. Apple later "opened up" iTunes so that music could be stored in formats compatible with other players. In making this decision, Apple understood that it would make the iTunes store more attractive and boost music sales, but might hurt iPod sales, so the net benefit might be positive or negative. In addition, Apple had to determine a pricing strategy for the iTunes store. Initially it set a price of \$0.99 per song. Assuming it wanted to charge the same price for all songs, was \$0.99 the "right" price? In 2009, Apple moved to a tiered pricing system in which many songs are still priced at \$0.99, but more popular songs sell for \$1.29 and less popular ones for \$0.69. Was tiered pricing a good idea, and how could Apple decide whether \$0.69, \$0.99 and \$1.29 are the "right" prices? Would Apple benefit by offering quantity and/or bundle discounts?

Similar strategic issues arose in the context of music streaming. In 2013, Apple launched iTunes Radio, a music discovery service similar to Pandora. In 2015 (after acquiring Beats for about \$3 billion), Apple launched Apple Music, which integrates paid downloads, streaming, and music discovery. Given that Apple continued to be the market leader in paid music downloads, it had to assess the potential advantages and disadvantages of offering a subscription streaming service in addition to the combination of music discovery (iTunes Radio) and paid downloads (the iTunes Store).

And then there is Spotify, which went public in April 2018 and at the end of the first day of trading, was valued at more than \$26 billion. By July 2018, despite growing losses, its market value had risen to \$33 billion, and it reached about \$40 billion by August 2021. Perhaps that valuation is justified: Spotify had over 70 million paying users at the end of 2017, and (by its own estimate) a 40% market share. By the end of 2020, it had 345 million users, of which 155 million were paying subscribers. But Spotify's main rivals in music streaming – Apple, Amazon and Google – have deep pockets, and could provide bundled services that might lure customers away. Will Spotify continue to dominate the market for music streaming, and earn substantial profits while doing so?

