Content is not king

Andrew Odlyzko
AT&T Labs - Research
amo@research.att.com
http://www.research.att.com/∼amo
Revised version, January 3, 2001

Abstract

The Internet is widely regarded as primarily a content delivery system. Yet historically, connectivity has mattered much more than content. Even on the Internet, content is not as important as is often claimed, since it is email that is still the true "killer app."

The primacy of connectivity over content explains phenomena that have baffled wireless industry observers, such as the enthusiastic embrace of SMS (Short Message System) and the tepid reception of WAP (Wireless Application Protocol). Combined with statistics showing low cell phone usage, this also suggests that the 3G systems that are about to be introduced will serve primarily to stimulate more voice usage, not to provide Internet access.

For the wired Internet, the secondary role of content will likely mean that the dangers of balkanization are smaller than is often feared. Further, symmetrical links to the house are likely to be in greater demand than is usually realized. The huge sums being invested by carriers in content are misdirected.

1. Introduction

The Internet is widely predicted to produce "digital convergence," in which computing, telecommunications, and broadcasting all merge into a single stream of discrete bits carried on the same ubiquitous network. The popular images of convergence are heavily tinged with the flavor of Hollywood. "Content is king" is the universal buzzword, where content is usually taken to mean professionally prepared material such as books, movies, sports events, or music. The race is supposedly to determine which organization or alliance will dominate in providing content to users, ideally in advanced multimedia formats. A recent article concludes that "[the Internet] has become a mass medium used mostly by relatively passive consumers, and as such major content providers will dominate it" [MargolisR]. The book [Winston] also presents the Internet as the next step in the evolution of mass media. Many industry leaders appear to base their strategies on this thesis. For example, at Global Crossing, its recent CEO, Leo Hindery, was attempting

> to turn this global Internet-based network into a mature content distributor. ... "I don't want to be anyone's dumb pipes," says Hindery. "If all you do is racks and servers, that's dumb. What we're doing is melding the network and the content."
>
> [Krause]

This preoccupation with content is not peculiar to North America. Norio Ohga, once CEO and recently chairman of Sony, says that "[w]ithout content, the network is nothing" [Schlender]. Juan Villalonga, until recently the chairman of the dominant Spanish communications carrier Telefónica, based his strategy on the belief that "[t]he key ... is content. Without it, ... phone companies risk becoming simple commodity pipelines" [Baker].

Unfortunately for these companies, content is not the key. Content certainly has all the glamor. What content does not have is money. This might seem absurd. After all, the media trumpet the hundred million dollar opening weekends of blockbuster movies, and leading actors such as Julia Roberts or Jim Carrey earn $20 million (plus a share of the gross) per film. That is true, and it is definitely possible to become rich and famous in Hollywood. Yet the revenues and profits from movies pale next to those for providing the much denigrated "pipes." The annual movie theater ticket sales in the U.S. are well under $10 billion. The telephone industry collects that much money every two weeks! Those "commodity pipelines" attract much more spending than the glamorous "content."

In the following sections I develop the argument that connectivity is more important than content. The evidence is based on current and historical spending figures. I also show that the current preoccupation by decision makers is not new, as similar attitudes have been common in the past. I then make projections for the future role of content and connectivity, and discuss implications for the architecture of the Internet, including wireless technologies.

2. Spending on content and connectivity

As is mentioned in the Introduction, movie theater revenues are tiny compared to spending on communications. Of course, movie tickets are only a small part of the movie industry revenues, and an even smaller part of the entire content industry. This section therefore presents a more comprehensive comparison. The final conclusion is still the same, namely that spending on connectivity is much more important for communication services than spending on content can ever be.

A reasonable objection to the comparison made below is that investments are driven by profits, not revenues. That is true. However, one cannot have profits without revenues. Further, profits of the

telephone industry have dwarfed those of Hollywood. Even if we look at profitability in terms of return on investment, it is not clear that movies have been notably more profitable than communications, especially if one adjusts for risks. Those who invested in Disney in the early 1980s (but not recently) have done very well, but Sony took a bath in its takeover of Columbia Pictures. Some creative talent has done very well. An outstanding example is Steven Spielberg, who became a billionaire, while minimizing his risks through careful structuring of his deals. On the other hand, for most actors and writers, the financial rewards are much slimmer and spottier, as Hollywood is very much a "winner-take-all" market. In communications the risks may also be rising, as the Iridium debacle demonstrates, but so are potential returns. At this moment Wall Street gets attracted primarily to the prospects for rapid growth, figuring that profits will show up some time in the future. While the actual returns that Wall Street seems to be expecting are almost surely ludicrously overoptimistic, the general principle appears valid. The histories of the telegraph and the telephone show the same pattern. Usually many companies jumped in with unrealistic hopes, most failed, but the industry as a whole prospered. Therefore this paper concentrates on revenues and growth rates of various sectors of the high-tech economy, and what they say about the current and potential role of content.

Table 1 presents statistics that show the relative sizes of several sectors of the U.S. economy. The data was drawn primarily from [USDOC], and the year 1997 was the most recent for which all the relevant time series were available. The detailed description of how the figures were obtained is given in the the paper [Odlyzko3]. There is considerable overlap in different categories in Table 1. For example, the $187.5 billion of advertising industry revenues pays for almost all television broadcasting, and that provides much of the funding for the movie industry. Further, consumer expenditures on phone services are already contained completely in the general telephone industry figure. Some of the categories, such as sporting goods and airlines, are included just for illustration.

What is striking is how highly valued communications is. If we combine the revenues of the phone industry with those of the postal service, we obtain a figure larger than military spending, and almost three times higher than the revenues of the airline industry. Just the spending on phone services is higher than all advertising outlays. So say good-bye to all those plans for financing the Internet through advertising! Yes, advertising can help fund some services, but it will not provide the generous revenue streams that are needed to support a communications infrastructure as large as the phone system. To obtain the funding that many dot-coms seem to be planning on, it will be necessary to get contributions from more than advertising. Ecommerce can help, but even that probably will not be enough, and it will be necessary to persuade people to pay for a large chunk of their communications. The question

is, what are people willing to pay for?

Table 1 shows that some advertising-supported business models might indeed be feasible. For example, sales of recorded music come to about $15 billion per year. If one eliminates the overhead costs of the physical distribution system for CDs (including music stores), one could probably provide the artists with as much money as they make now, and the music labels with as much revenue for their central selection and promotional activities (and their profit) as they make now for under half of the $15 billion. That would be about half of the advertising revenues that the radio industry collects for broadcasting music. Getting that much extra funding from advertising might be possible for an Internet music service that allowed listeners much greater selectivity and thereby led to more listening (as Napster appears to be doing on college campuses). However, such a move appears feasible only because recorded music is a relatively small market. We could not hope to obtain enough advertising funding to pay for anything as large as the phone system.

Although Table 1 makes a powerful case by itself, it is worth reiterating the basic theme, which is that the vaunted "content" is not where the action is. The postal system alone collects almost as much money as the entire movie industry, even though the latter benefits from large foreign sales. For all the publicity it attracts, entertainment is simply not all that large, because people are not willing to pay very much for it. The dream of the early 1990s of financing the "Information Superhighway" through "500 channels to the home on the cable TV network" was an obvious fantasy.

Content is not only a small part of the economy, it is often paid for indirectly. Well over two thirds of newspaper revenues, and almost all of broadcast TV and radio revenues come from advertising. Thus content is being given away in order to attract people to goods and services they are willing to pay for. Although spending for content (whether by consumers or advertisers) has been rising, it has been doing so at a sedate pace, and is unlikely to explode.

One could object that Table 1 proves just the opposite of what is claimed above. After all, this table shows that even if no single content segment collects anywhere near as much money as the phone system, in aggregate huge sums of money are being spent on content. In particular, household spending on content is over 50% higher than on phone services. There is some issue of what one means by content, a question we will return to later. If we take a generous interpretation, we can come up with total content industry revenues comparable to the $256 billion that the telephone industry collected in 1997. (This would include household spending as well as business information services and advertising revenues of broadcast industries.) However, comparing just the total revenues of those two industries is misleading. In the case of the telephone industry, the $256 billion does include some service revenues

Table 1. Selected sectors of U.S. economy.

industry	1994 revenues (billions)	1997 revenues (billions)	annual growth rate
telephone	\$199.3	\$256.1	8.7%
long distance	81.0	98.5	6.7
wireless	16.8	33.5	25.9
U.S. Postal Service	49.6	58.3	5.5
advertising	151.7	187.5	7.3
motion pictures	53.5	63.0	5.6
movie theaters	6.2	7.6	7.0
video tape rentals	7.0	7.2	0.9
broadcast industries			
television broadcasting	31.1	36.9	5.9
radio broadcasting	10.5	13.5	8.7
newspapers	47.2	55.3	5.4
magazines	17.4	19.9	4.6
consumer spending on “content”	113.9	133.5	5.4
subscription video	29.2	41.5	12.4
home video (rental and purchase)	17.8	20.4	4.6
home video games	3.1	4.4	12.4
newspapers	12.8	13.6	2.0
consumer magazines	9.5	10.1	2.1
consumer books	20.2	20.9	1.1
recorded music	14.7	14.9	0.5
consumer spending on phone service	70.5	85.4	6.6
sporting goods sales	53.5	64.1	6.2
airlines	88.3	109.5	7.4
national defense	281.6	270.5	−1.1

as well as yellow pages advertising, but the overwhelming majority of that money is for simple transport of voice and data. The content industry as a whole, though, has to use its revenues to pay for content as well as the delivery of the content. The creative souls who command $20 million per movie know their value, and do manage to appropriate the lion's share of the profits from such enterprises, while keeping their risks lower than those of the investors. Similarly, the professionals who compile the Lexis database, or assemble and monitor Reuters' financial data feeds, have to be paid, just like movie actors and musicians. Even if their average pay is lower, there are more of them, and their payroll, as well as all the equipment and overhead needed to support their work, are not inexpensive. Hence only some of the revenues of the content industry contribute to the communications infrastructure. Since this work is concerned with the future of the Internet, it is the present and potential funding for the network that matters.

That only a fraction of the revenues of the content industry go for delivery is an important point that has analogs in the context of ecommerce. Ecommerce is already big, and is exploding. However, what does that mean for the network? A dollar of ecommerce transactions does not mean a dollar devoted to the network. When that sterling example of ecommerce, Amazon.com, sold $1.6 billion of goods (primarily books) in 1999, it is likely that only a few million dollars of the $2.3 billion of its costs went for Internet connectivity. Considerably more, but (judging from its financial reports) still only around $150 million, went for the servers, software development, and other information technology products and services that are needed to stay competitive in this rapidly changing field. If the Amazon figure of $1.6 billion is to represent the ecommerce opportunity for the Internet, then t-commerce ("t" standing for "telephone", and covering all deals that use the phone in any way) amounts to tens of trillions of dollars. (Yes, more than the GDP, since the wonderful accounting of the ecommerce world surely would let us count the same value several times, as it passes through multiple transactions that all use the telephone at some stage.) The contribution of ecommerce to communications is growing, but it has to be kept in perspective.

Communications is far from being the largest segment of the economy. It is smaller than cars, housing, food, and especially medicine. It is also about two thirds the size of the primary and secondary education sectors, and comparable to the higher education enterprise. The main point, though, is that communications is huge, and represents the collective decisions of millions of people about what they want. It is also growing relative to the rest of the economy in a process that goes back centuries. As a fraction of the U.S. economy, it has grown more than 15-fold over the last 150 years. The key point of this section is that most of this spending is on connectivity, the standard point-to-point communications,

and not for broadcast media that distribute "content."

There is at least one prominent technology that initially moved from connectivity towards content, namely radio. It started out as a point-to-point communication system, the "wireless telegraph." After about two decades of experimentation, it became primarily a broadcast medium. (For the history of this transformation, see [Douglas, Smulyan].) However, the role of radio in the economy as a content delivery technology is tiny compared to that of the telephone, as Table 1 shows. Further, in the last few decades, with the development of cellular services, radio transmission has started to move back to its roots as a point-to-point communications service. The revenues from wireless telephony already far exceed those from radio broadcasting, as Table 1 shows ($33.5 billion versus $13.5 billion in 1997, with the disparity much greater today).

The predominance of point-to-point communications spending is not new. That has been the historical pattern for ages. For example, in the early 19th century, almost all the revenues of the U.S. postal system came from letters. Yet about as many newspapers as letters were being delivered.

3. History of preoccupation with content

The preoccupation of decision makers with content and broadcast communication is also not new. In the early 19th century, the explicit policy of the U.S. government was to promote wide dissemination of newspapers. They were regarded as the main tool for keeping citizenry informed and engaged in building a unified nation. Hence newspaper distribution was subsidized from profits on letters, as is discussed at greater length in Section 12 of [Odlyzko3]. The extent of the subsidy may be gauged by the fact that "[i]n 1832, newspapers generated no more than 15 percent of total postal revenues, while making up as much as 95 percent of the weight" (p. 38 of [John]).

The policy of the U.S. government to promote newspaper "content" at the expense of person-to-person communication through letters may or may not have been correct. It would be a hard task (and one well beyond the scope of this work) to decide this question. However, there are reasonable arguments that the preoccupation with newspapers harmed the social and commercial development of the country by stifling circulation of the informal, non-content information that people cared about. In the 1840s, responding to public pressure, Congress did reduce letter rates, which resulted in increased usage, and changed patterns of usage, as is described at greater length in Section 12 of [Odlyzko3]. In those days, the government understood clearly that what people were willing to pay for was letters, and that newspapers were being subsidized. The Post Office would have thrived on letters alone, but would have gone bankrupt instantly had it been forced to survive on newspaper deliveries. Thus content was

king in the minds of policy makers, but it was definitely not king in terms of what people were willing to pay for. That is similar to the current situation. However, this differential in willingness to pay does not seem to be understood as well today as it was then.

Preoccupation with content has historically been common. For example, it was often thought (even by Alexander Graham Bell) that one of the principal uses of the telephone would be in broadcasting [deSolaP1, deSolaP2]. Several substantial experiments in delivering content over the phone were attempted, including the Telefon Hirmondó in Budapest that lasted from 1893 past the end of World War I, and the Telephone Herald in Newark, New Jersey, which folded soon after its start in 1911 [deSolaP1]. In the end, though, the phone emerged as the prototypical example of point-to-point communication. The standard history books do not explain convincingly why this occurred. However, there is plenty of evidence for anyone interested enough to investigate this issue. For example, according to [Denison], the annual subscription for Telefon Hirmondó was 18 forints (about $7.50 in U.S. currency of that time), while regular phone service cost 150 forints per year. With customers willing to pay over 8 times as much for connectivity as for content, is it any wonder that the Telefon Hirmondó did not flourish?

4. Content and the brave new world of the Internet

A skeptical reader might say that all this historical stuff is amusing but irrelevant. We live in the 21st century, and our high-tech present as well as our future are on the Web, where content is universally regarded as king. Studies of the Internet regularly find that Web traffic makes up 60 to 80% of the bytes that are transmitted. Certainly most of the commercial development effort on the Internet and almost all the attention are devoted to content. Thus even if content was not king in the early 19th or late 20th centuries, it might be king in the 21st.

There are three counterarguments to the above objection, all of which support the "content is *not* king" thesis. All argue that the dazzling success of the Web has created a misleading picture of what the Internet is, or is likely to evolve towards. One argument, to be discussed in more detail later, is that the future of the Internet is not with the Web, but with programs like Napster or (even more, because of its decentralized nature) Gnutella, which allow for informal sharing of data.

The second argument is that content is not king of the Web. Most of the traffic on the Internet is corporate (especially if we include internal intranet traffic that is not visible on the public backbones). It is likely that in early 2000, under a third of the volume went to residential users [CoffmanO1, CoffmanO2]. Intranet traffic appears to be much less heavily biased towards the Web than that of private

individuals. Furthermore, even the traffic that appears to be Web-based frequently represents a variety of database transactions that are not properly speaking "content." Because browsers are a user-friendly tool that is ubiquitous, a multitude of services have been squeezed into a Web framework. They help perpetuate the image of the Internet as primarily a content-delivery mechanism. (Note that the Web was invented to allow scientists to communicate with each other and access data, not for content delivery.)

The third and final argument is that even if content were king on the Web now, the Web is *not* king of the Internet. This may again seem absurd, especially in view of the statistics quoted above, that most of the Internet traffic is Web transfers. However, consider again the U.S. postal system of 1832. Content certainly dominated in terms of volume of data. Newspapers sent by mail weighed about 20 times as much as letters. Further, the density of printed matter is higher than of handwriting, and a typical copy of a newspaper was likely read many more times than a typical letter. Hence newspaper "content" was probably delivering at least a hundred times as much information as letters. But volume is not the same as value. Letters were bringing in 85% of the money needed to run the postal system in 1832. On the Internet in 2000, it is email that is king, even if its volume is small.

Today, Web traffic dominates the Internet in volume, with about 20 times as many bytes as email. (Netnews traffic volume is of about the same order of magnitude as email. The fractions of total traffic created by these two services vary from link to link and from day to day.) Even a decade ago, before the Web, email typically accounted for under 10% of Internet volume. Yet email has been and continues to be the real "killer app" of the Internet. The ARPANET (the progenitor of the Internet) was built primarily to connect computers. Yet email quickly emerged as the application that mattered the most to users, even in the early days of the network. This was much to the surprise of the system's designers [LickliderV].

> The popularity of email was not foreseen by the ARPANET's planners. Roberts had not included electronic mail in the original blueprint for the network. In fact, in 1967 he had called the ability to send messages between users "not an important motivation for a network of scientific computers" . . . Why then was the popularity of email such a surprise? One answer is that it represented a radical shift in the ARPANET's identity and purpose. The rationale for building the network had focused on providing access to computers rather than to people.
>
> [Abbate]

More recent surveys (e.g. [KatzA, Pew]) show that email is still the most valuable service. Ask people whether they would rather give up email or the phone, and the responses will typically be split. However, when a similar choice is offered between the Web and email, there is no contest. This is true for both individuals and large organizations. Intranets are all the rage, but it is email that makes enterprises run.

The perception that content dominates the Internet is fueled by studies such as [AdamicH], which show the winner-take-all phenomenon, with a few sites dominating Web transactions among residential users. However, one should not read too much into such results. In the early 19th century postal system, studies of usage of information would undoubtedly have reached conclusions similar to those of [AdamicH]. Most data from distant locations that people consumed came from newspapers. Further, circulation figures of individual newspapers probably followed the standard Zipf-type distribution, with the most popular papers attracting a disproportionately high fraction of readers. Yet that does not say much about the value derived from the postal system, which was elsewhere, in letters.

To reemphasize the importance of point-to-point communication in the online environment, consider the disappointing reception that WebTV has had. It seems that inexpensive Web browsing is not such a great attraction by itself. Also consider the innumerable failures in teletext experiments (cf. [Ettema, Greenberg, Klopfenstein, Noll]), as well as the initially promising start but disappointing end of the French Minitel. Their inadequate or even totally missing facilities for point-to-point communication appear to have been fatal errors. Next, consider the fates of CompuServe and Prodigy. Set up primarily for database access and online shopping, respectively, both were forced to emphasize communications and are now basically standard ISPs. Finally, the currently most successful of the public online services, AOL, started out as a game network. The figure in Table 1 showing small video game spending explains why that approach was doomed to failure. (The game market is growing, and in any case is larger than the figure in Table 1, which covers just the home part of it. It can certainly contribute to profits of large networks, or support some specialized service providers. However, it simply cannot fund anything as large as AOL.) AOL survived and prospered because it was nimble. After several changes in strategy, it partially opened itself up to the Internet. While it has content of its own, and access to the Internet, the majority of the time its subscribers spend online is devoted to email and chat.

What this argument suggests is that the Web (and browsers in particular, which made the Web user-friendly) may have created a misleading impression. By focusing attention on centralized delivery of content, the Web may have prevented a proper appreciation of the importance of the often chaotic and generally unplannable point-to-point communications. The Web and the browsers may have played

two main roles. One was to force online service providers to accept an open interoperable standard that made the entire Internet accessible for communications for everyone. The other was to introduce a user-friendly graphical interface for email, chat, and netnews, which made such communications easier. However, the Web is not as important to the Internet as is commonly thought.

5. Wireless communications

As an example of the relative value of content and simple pipes, note that the revenues of the entire cable TV industry in 1997 were only slightly higher than for the cell phone carriers. Furthermore, as Table 2 shows, cable TV has been growing far more slowly than the wireless industry. Yet cell phones currently provide primarily simple, low bandwidth pipes. By early 2000, even the gross revenues of radio telephony exceeded those of the cable TV industry. Further, a large chunk (estimated at a quarter to a third) of cable revenues was devoted to paying for content, so in terms of basic network revenues, the cellular industry had pulled ahead even before 1997. The comparison is even more favorable to low bandwidth wireless pipes when we go outside the U.S. In other industrialized countries, cell phones are often much more widely used, while cable TV penetration is almost always far lower than in the U.S. Thus on a worldwide scale, the comparison is skewed even more heavily against content. The cable TV industry does have excellent prospects for faster growth. However, that growth will surely come more from improved communication capabilities, and less from content.

Table 2. Revenues of U.S. cable TV and cell phone industries.

year	cable TV (millions)	cellular (millions)
1987	$11,563	$942
1992	21,079	6,688
1997	30,784	25,575

Although the wireless industry has done very well selling low bandwidth pipes for connectivity, it appears determined to repeat the mistakes of the previous communications technologies in the near future. In particular, this industry appears preoccupied with content. The new third generation (3G) systems that will be introduced around the world in the next few years will provide considerably higher bandwidth than current ones. This bandwidth is universally touted as a way to provide Internet access, and in particular to sell content to users. Yet the Wireless Application Protocol (WAP), designed to deliver content to wireless devices, has been a disappointment so far, surprising the industry. On the

other hand, the Short Message System (SMS), providing low bandwidth digital messaging between users, has surprised observers by its success. For example, in the U.K., between the second quarter of calendar year 1999 and the second quarter of 2000, the number of SMS messages grew from 159 million to 1.42 billion [Oftel]. Yet in view of history, there should have been no surpise here at all. SMS provides connectivity, WAP provides content. Therefore it is completely consistent with all of human history, and should have been completely predictable, for SMS to be more popular than WAP.

What should the cellular operators do? They should be striving to increase voice calls on their systems. Although this is not widely known, cell phones are used very infrequently. For example, in the U.K., average usage of a cell phone dropped from 4.8 minutes per subscriber per day in the second quarter of 1999 to 4.2 minutes a year later [Oftel]. (To be more precise, the drop was from 3.5 minutes of outgoing calls and 1.3 minutes of incoming calls to 3.2 and 1.0 minutes, respectively. Similar drops, and similar average usage figures, apply also to many other countries, including Denmark, Finland, and New Zealand.) At the same time, the average usage of a wired phone in the U.K. increased from 15.7 minutes of outgoing calls per day in 1999 to 17.3 minutes a year later. Although up to a third of the wired minutes are for Internet access, this does show that wired phone usage is far higher than that of cell phones. The reason for the drop in average daily usage is that new subscribers are being recruited largely through the pre-paid plans, which tend to limit usage.

The low usage of cell phones refutes the frequently heard claims that wireless telephones are beginning to displace wired ones. Given the higher growth rates in wireless minutes than in wired ones, such a displacement will likely occur, but it is still far in the future. At this moment, wired phone usage is growing. In the U.K., for example, looking at the data in [Oftel], we see that between the second calendar quarters of 1999 and 2000, fixed line calling grew by 7.03 billion minutes, from 47.22 billion to 54.25 billion, while cell phone calling grew from 5.0 billion minutes to 8.39 billion minutes. Thus the growth in wired phone usage over that year was larger than the total volume of cell calls at the beginning of that period. A closer analysis of the statistics in [Oftel] suggests that this growth was due entirely to increased Internet usage, and that voice usage did drop slightly, presumably because it was diverted to cell phones. Still, total wired usage grew vigorously. Even if we consider just voice calls, each wired phone in Britain is used for about 22 minutes per day for voice calls. One does not replace that with a cell phone that is used 4 minutes per day! On the other hand, it suggests that there is much more that can be done to stimulate voice usage. That this is feasible is shown at least partially through the experience of the U.S. Historically, in all countries average cell phones usage has been decreasing steadily, as the influence of the early heavy users has been diluted. However, recently usage in the U.S.

has increased. According to a press release from the U.S. cell industry association [CTIA], between the last quarter of 1998 and the last quarter of 1999, subscribers have increased their local calling from an average of 130 minutes per month in the last quarter of 1998 to 180 minutes per month in the last quarter of 1999. (Wired phones are used for about an hour each day in the U.S.) This increase was almost surely caused by the spread of block pricing plans, starting with the introduction of the AT&T Digital One-Rate™ plan in 1998. In these plans users purchase a fixed number of minutes to be used in a month. Such plans have the effect of stimulating usage [Odlyzko3]. Their success in the U.S. demonstrates that creative pricing can be used to increase voice usage. (For those complaining of "cell-phone rage," this must be a frightening prospect!) In addition to generally lower prices, as well as block pricing plans, or flat rate plans, the industry could stimulate more voice usage through introduction of toll-free numbers for wireless calls. If United Airlines is willing to pay for people to call it on wired phones, shouldn't they be willing to pay for them to call from cell phones?

The arguments above suggest that the main role of 3G wireless systems should be to stimulate voice usage. That is not what the industry is planning, but the systems that are being developed are flexible enough so that even if their intended purpose of providing content is not lucrative, they can still be used for more voice calls. The arguments of this paper predict that the industry will end up doing this without planning on it. However, it would be more productive for them to think along these lines from the beginning. In particular, content, location based services, and related novel features are probably best thought of as ways to induce more voice usage, through making the cell phone more widely useful. The Japanese i-mode system may foreshadow how other countries' wireless industries will evolve. Reportedly, the spending on digital data transmission (much of it SMS) by i-mode users is matched by their increased spending on voice calls.

As a final historical perspective, let us note that the wired telephone industry did not attain its current role until it started to encourage usage, especially social calls. The fascinating story of this development is told in [Fischer]. It is also discussed later in this paper.

6. The role of content

The general conclusion is that content has been less important than point-to-point communication in the past, including the recent past involving the Internet. Still, the argument that "content is *not* king" that is presented here should not be taken to an extreme. All it says is that most of the money is in point-to-point communication. It does not say that content does not dominate in volume of data. Historically, as we have noted above, content has often dominated, and probably dominates now. (There

is some uncertainty, since there are difficult questions about measuring the volumes of broadcast communications.) There are arguments, to be presented later, that in the future, content will not provide most of the bits traveling on the Internet. However, even if that prediction is wrong, it will not affect the argument, which is about value to customers, and not about volume.

That content is not king does not mean that content is unimportant in shaping political or social views. The attention paid to writers, and the political advertising on radio and TV, testify to the influence of content. This also is not a new phenomenon. Over the centuries, millions of people based their opinions of Richard III on Shakespeare's play, just as today millions base their opinions of John F. Kennedy's assassination on Oliver Stone's film.

The argument about the value of content says little about the dispute in early 2000 between Disney and Time Warner over carrying ABC channels on cable TV. That issue is about division of revenues between content creation and content distribution. The argument of this paper is that the entire content piece of the economy is not all that large, and its contribution to network costs is much smaller than that of point-to-point communication. It does not deal with how the content piece is divided.

Content can be profitable. Numerous media companies are doing very well. Content can also be of value to a network, even aside from providing traffic for the network to carry. However, it is probably best to think of content as either catnip or icing on the cake; something to attract new users, or enhance user experience. That is what broadcast TV programs do for the advertisers who pay for them. That may also have been the main role of the Web and browsers in bringing more people to the Internet.

7. The future of the Internet

What the argument that content is not king does say is that people are willing to pay far more for point-to-point communication than for the famed content. That is likely to be reflected in what kinds of networks are built, and which companies succeed. It inverts the usual ordering of priorities, making point-to-point communication central, and content secondary. The fights over control of movie distribution may be a distraction from the main business of communication. As a simple example of what this may mean in practical terms, most broadband access links, such as cable modem and DSL ones, are designed to be asymmetrical, with higher capacity on the link to the home than to the network. The expectation is that these connections will be used primarily to pull content to the consumer. However, if the consumer places much higher value on personal communication than on content, the case for symmetrical connections becomes stronger. That may mean that fiber to the home may be justified sooner than expected. In the wireless arena, it suggests (as is explained in an earlier section) that for much

of the next decade, the best strategy will be to emphasize regular voice transmission, supplemented by email and various low-bandwidth data transfers. Music and video services are likely to be delayed until much later.

Before continuing, it is worth considering a basic issue, namely, what is content? This word derives from the Latin "contentum," which means "that which is contained," but this derivation is not very descriptive. There is no precise definition, but generally content is used to denote material prepared by professionals to be used by large numbers of people, material such as books, newspapers, movies, or sports events. That is the sense in which it is used in this work. In general, content is distributed by "mass" or "broadcast" communications systems. Until a few decades ago, such services could be distinguished easily from "point-to-point" (or, more precisely, "person-to-person") communications, which included first class letters and phone calls, and were specific to the people involved in the transaction. These two types of communications were sometimes combined during distribution, as in the postal system, which carried both letters and newspapers, in an early example of "convergence." However, there was a noticeable distinction in how these two types of communication were prepared, handled, perceived by the recipients, and (a point discussed at great length already) in how much people were willing to pay for them.

During the last few decades, the distinction between point-to-point and broadcast communication began to blur. Computers allowed for the mass preparation of personalized letters offering credit cards, say. Answering machines and voice response systems led to machine-mediated point-to-point communications. Individuals were able to reach large audiences through postings to netnews, or, more recently, through their personal Web pages. We can expect this evolution of communications to continue, and eventually to achieve that convergence in which there will be a continuum between point-to-point and broadcast communication. However, we are not there yet, and won't be for a while.

In this work I do not classify information services such as weather, directory assistance and airline schedules as content. Many of the standard phone calls access just such services, and the Internet is leading to increasing usage of them. I also do not classify most of ecommerce as content. Somebody going to the Godiva Web site may be exposed to creative work in the ads flashed on the screen, but is interested in purchasing a tangible good. These types of interactions will flourish on the Internet, and some will be merging with content, but they are more typical of the standard point-to-point communications.

8. Rates of technological change

One of the main lessons from the history of communications is that technologies are often adopted rapidly, but seldom at the astronomical rates that popular imagination associates with the Internet. This applies even to the Internet, where change tends to be less rapid than is often thought. Browsers were adopted rapidly. The first informal release of Mosaic took place in the spring of 1993, and in under two years, the majority of Internet traffic was Web-related. However, that was an exception. Other changes have been slower. Just consider Internet telephony, introduced back in 1995. It is finally beginning to have a noticeable effect, but it is far from dominant. As another example, Amazon.com has had a striking impact on perceptions of ecommerce. Yet after more than 6 years, less than 10% of book sales take place online, and Amazon.com's investors are learning the virtues of patience. "Internet time" is a myth. In general, the time a new technology takes to become widespread has not changed much in the last half century.

> A modern maxim says: "People tend to overestimate what can be done in one year and to underestimate what can be done in five or ten years."
>
> (footnote on p. 17 of [Licklider])

Even technologies with compelling advantages tend to take a decade to dominate markets. Fax machines took about 10 years, from the introduction of the first inexpensive models until they became ubiquitous. Cell phones, one of the fastest growing industries, have taken about 15 years to reach their present level. Cable TV has taken over three decades to reach about 60% of U.S. households. Music CDs and more recently DVDs show similar patterns, taking on the order of a decade to reach dominance. For more examples and a discussion of rates of change, see [Odlyzko1]. Aside from the unusually rapid ascendency of the browser-Web combination, fast change is usually associated with the presence of forcing agents. These can be either governments or a small number of key decision makers who can shift an industry's direction. An example of such forcing agents are the information technology managers at large banks and other enterprises. When they decided that mainframes were obsolete, they did so over a short period of time, and this led to a catastrophic decline in IBM's fortunes. A transition of voice phone traffic from circuit switched transmission to the Internet might occur rapidly for just this reason. The carriers might be able to implement it rapidly, since it could be done essentially invisibly to the end users, and the decisions would need to be made by only a few people.

The decade-long diffusion periods listed above for consumer goods and services are due to the inertia of the millions of people who have to individually decide to adopt a new technology. Most new

products and services are in that category. Sociological changes are even slower, taking a generation or two. Normal change, with a simple shift in technology that offers serious advantages over older, more established competitor (as with CDs over vinyl records, which provided higher quality sound reproduction, or cell phones, which offered mobility, even at the cost of sound quality), takes on the order of a decade.

9. Content in the future

The speed with which new technologies diffuse has a direct relevance for the question of whether content might be king of the Internet. It is possible to make a case that even if content is not king now, it might be king in the future, when convergence does occur. Some evidence for this can be derived from the comparison of cable TV and cell phone industries. Their revenues and growth rates were cited as demonstrating that point-to-point communication is more important than content. However, there is another way to look at the data. As was mentioned, about a third of the cable TV revenues go to pay for content. What that means is that two thirds pay for the network. (According to some reports, carriers receive up to 90% of the revenues from some content, such as hard-core pornography pay-per-view movies.) If convergence moves delivery of most of the content to the Internet, and transport grabs two thirds of the total revenues from content, then the network will get a huge new source of revenue. Total content spending in the U.S. is comparable to that on the phone system, so two thirds of that would make a huge difference to network financing. This scenario is not totally implausible, since the current content distribution system is grossly inefficient. Book authors and musicians typically receive in royalties less than a tenth of the price consumers pay for their creations. It is a striking observation that a participant in Amazon.com's affiliate program can sometimes get more money from a book sale generated by a link from his or her home page than the author does from royalties! The Internet offers a chance to reduce some of the inefficiencies of the current system. For the current dominant content producers, the real threat from the Internet is probably less from piracy, and more from disintermediation. New producers can come in and, unburdened by the high overheads and obsolete habits of established players, can offer better deals to both the creative talent and the consumers.

The scenario outlined above, in which Internet transport grabs the lion's share of revenues from content, is conceivable, but very unlikely. One argument against this scenario is based on a simple historical observation. No broadcast medium has ever been replaced by another; despite predictions to the contrary at various times in the past, newspapers were not killed by radio, nor radio by television. However, that argument may not be valid. The Internet is a disruptive technology, it does have

unprecedented ability to emulate other delivery mechanisms, and we are already seeing rapid growth in music delivery on it. As an example of what can happen to even the most solid-seeming businesses, just consider the *Encyclopaedia Britannica*. (Its problems started even in the pre-Internet days, with CD-ROMs.) In spite of having the greatest brand name and by far the best content in the encyclopedia field, it has been floundering, and has yet to find a viable business model. Thus dramatic changes are indeed possible in the electronic environment. Still, there are other, more substantial, arguments against the content thesis.

The Internet will surely have a major impact on the content industries. However, as was discussed above, consumers are slow to change their behavior. Even the *Encyclopaedia Britannica* has had more than a decade in which to flounder. Couch potatoes are not going to abandon their TV sets right away, especially when computer and cable TV penetrations in the U.S. are under two thirds of households, and not growing rapidly. Even in the business environment, adoption of new technologies that require a thorough re-engineering of all internal processes is slow. The business-to-consumer dot-coms have discovered this already, and the business-to-business ones are in the process of learning. Although we are living in the Internet era, fundamental change is not all that much faster than a century and a half ago. The adoption of the telegraph by railroads, discussed in Section 13 of [Odlyzko3], did lead to huge efficiency gains, but it was slow as well.

Slow adoption of new technologies means that convergence will be spread over a decade or more, and there will be continuing competition from traditional media, as well as increasing diversity of delivery mechanisms for content. This may mean that writers and artists will get a bigger share of the pie. That appears to have been the trend over the last few decades, with movie actors and professional sport stars increasing their share of the revenues their work brings in. It is less certain whether carriers will manage to improve their share of the content pie to the same extent. There will certainly be a shift of revenue towards broadband services, but content distribution may not be the largest contributor to it.

The main reason to question whether content will ever make giant contributions to network costs is that by the time convergence is likely to occur, at least a decade into the future, content transmission is likely to be a small fraction of total traffic. Further, most content will probably be distributed as ordinary file transfers, not in real-time mode. The various rates of growth that contribute to these predictions are discussed later. Right now we note that if these predictions come true, then it will be hard for networks to charge much for the transport of content. High prices could be charged for content distribution if content made up most of the traffic, or else if content required special transmission quality (such as that needed for real-time streaming traffic). Since neither of these conditions is likely to be satisfied,

though, content will probably constitute just some of the huge number of large files, many encrypted, that will be flying around the network. How could carriers pick out the content files for special pricing?

Let us next consider the predictions for Internet traffic mentioned in the preceding paragraph. I will treat them briefly, and refer the reader to [CoffmanO2] for more detail. Internet backbone traffic appears to be about doubling each year. Further, advances in photonics and additional fiber deployment appear to allow for a doubling of network capacity each year for the next decade. In early 2000, Internet backbone traffic in the U.S. appeared to be less than a third of voice traffic in volume, but is likely to become larger by about 2002, with the transition point slightly later for the rest of the world. However, if voice traffic were to be packetized, it would almost surely be compressed, and then its volume would already be less than that of Internet traffic (at least in the U.S.). Broadcast TV would still overwhelm the Internet of the year 2000, but at 100% annual growth rates, it will not be too long before there is more than enough capacity to provide a high quality video channel for every person on Earth. This is because bandwidth that is likely to be required to satisfy any single person's real-time transmission needs will not be increasing fast.

The versions of Moore's Law that hold in different industries operate at diverse rates. Microprocessors are doubling in computing power every 18 to 24 months, while fiber transmission capacity is doubling every year. On the other hand, display technology is advancing extremely slowly. Broadcast TV resolution has been static for several decades, and even the planned move to HDTV will require only a modest increase in bandwidth. Thus satisfying the needs for real-time multimedia transmission will not require much of the Internet's capacity.

Content is likely to form only a small fraction of Internet traffic for reasons explained above. In addition, real-time delivery of content is likely to be an even smaller factor, for reasons discussed in much greater detail in [CoffmanO2]. Transmission capacity is approximately doubling each year, which is a much faster rate of improvement than Moore's Law for semiconductors. However, hard disk storage capacity is also about doubling each year. Furthermore, that capacity is already huge. At the beginning of 2000, the U.S. Internet backbones appeared to be carrying about 12,000 TB (terabytes) of traffic each month. However, the total world hard disk capacity was 3,000,000 TB. Thus it would take about 20 years to transmit all the data on those disks over U.S. Internet backbones. Nobody proposes to do that (and why would anyone want to send all the duplicate copies of Windows 98 around, in any case?), but this comparison helps in visualizing the technology landscape. The presence of huge local storage capacity in local PCs or cable TV setup boxes will make it much more attractive to send even content as files, not as real time transmissions. There will be a growing volume for real time

multimedia traffic, for applications such as videoconferencing. However, such applications are likely to be swamped by ordinary file transfers. The dominant mode of operation is likely to be fast (eventually much faster than real time, but initially often slow) download to local storage, fast transfer to whatever display device one wishes to use (often a mobile information appliance), and then playback. That is already the model we see emerging with MP3, Napster, and TiVo. The advantages of this model include the ability to implement it now, before the Internet can be made ready for real-time streaming media. It also accommodates gracefully the forecasted explosive growth in small mobile devices, which will often have small storage and low bandwidth over wireless links, and thus will be most useful if they can get data from local storage. This model also allows for easy integration with special hardware for intellectual property protection.

That real-time multimedia traffic would not dominate the Internet has been predicted several times in the past. It is an obvious conclusion from the rapid increase in traffic. Already the authors of [deSolaPITH] noted that in the early 1980s data traffic was growing much faster than voice communication. They observed that if that trend continued, eventually most transmissions would not be seen by human eyes nor heard by human ears. In a similar vein, in discussing general digital data volumes in 1997, Michael Lesk predicted that "the typical piece of information will *never* be looked at by a human being" [Lesk]. Bill St. Arnaud appears to have been the first one to predict in the specific context of the Internet that the general expectations for streaming multimedia domination were unlikely to come true [StArnaud]. Further arguments were presented in [Odlyzko2].

The huge volume of local storage will surely stimulate the generation of non-content traffic. Both corporations and individuals so far have had no difficulty filling their disks with data. We can expect this to continue, although predicting the exact source of that data is uncertain. For firms, various databases will likely continue to proliferate and grow. For residential users, pictures are the leading candidates for filling those disks. Ease of use, lower cost, and instant gratification all stimulate use, and digital camera owners appear to be taking many more pictures than they ever did with regular film. The same electronic technology that is producing better disks and processors is also producing better cameras. Historically, it appears that privately taken pictures have traditionally been the dominant source of data. An interesting accounting of all the information stored in the world in 1997 by Michael Lesk [Lesk] found that home photographs were the dominant component. (For a more complete and up-to-date accounting of information, see [LymanV]].) They contributed about 500,000 TB each year (even when one assumes that each picture is stored as a modest 10 KB JPEG file). By comparison, all the texts in the Library of Congress amounted to around 20 TB, while the graphics and music in that collection

came to about 3,000 TB. Thus even this great library contained less than 1% of the world's information. (The publicly accessible Web pages currently contain a few tens of terabytes, just a few percent of what the Library of Congress has, but comparable to the text collections in that library.)

An obvious comment to the estimates above is that the purpose of a library is to select the most valuable material, and that most of those photographs contributing to the 500,000 TB are of no interest to most people. That is true, but that does not stop those pictures from being taken, and it will not stop an explosion in volumes of data collected this way in the future. A few pictures or video clips will turn out to be of great interest, in spite of amateur production. Just think of the Zapruder film of the JFK assassination, or the Rodney King video. More importantly, many of the pictures being taken are of interest, or might be of potential interest, to at least one person. Most of the world will have no interest in a picture of your newborn baby, but your mother will cherish it. Similarly, in the future you will be taking digital video clips of your children and sending at least some of them to your mother. Many of the video shots will intentionally be made with the hope of that nobody will want to see them, as with security monitors. (Note that some of the earliest applications of miniature taperecorders and video cameras has been to snoop on child care providers. There are obvious privacy implications of current and future camera technologies that are not pursued here, but are discussed in [Garfinkel], for example.)

Other examples of data that may be filling our disks are suggested by the entry in Table 1 for sporting goods. Spending in this area comes to about half of consumer spending on content, showing how highly these products are valued. One can easily imagine future generations of body and equipment sensors that would record precisely all details of a player's movements in tennis, say. These details would then be fed into systems that would analyze the motions, compare them with previous games, and produce high quality graphical displays to help improve the player's game. There is practically no bound on the amount of data that could be generated this way.

The data that will be generated is likely to be shared using programs descended from Napster. Email and the Web may not be flexible enough. Napster is currently attracting huge attention because of the threat it poses to conventional music distribution channels. However, that may turn to be less important than its ability to facilitate sharing of files. Napster itself is too limited, as it is designed to handle just MP3 music files, and is also centralized. Yet it has already inspired creation of tools such as Gnutella, which are much more general and decentralized. Given the growth of local storage, and the increasing availability of tools to fill that storage with video clips and other material, it is possible that tools like Gnutella may become more important to the Internet than the Web.

10. Value of social interactions

The discussion above is futurology. We cannot be certain how the Internet will evolve. However, history teaches us several lessons. One is that the growing storage and communication capacities will be used, often in unexpected ways. (For a careful study of the many early predictions about the future of the telephone, and the actual evolution of that service, see [deSolaP1, deSolaP2], for example.) Another important lesson is that the value of the myriad social interactions has often been underestimated. Only a tiny fraction of the information passing through communications systems has ever been high quality scholarly knowledge. Even in more prosaic transmissions, we have moved from Samuel Morse's solemn "What hath God wrought?" to Alexander Graham Bell's utilitarian "Mr. Watson, come here, I want you," to the banal "How was your lunch?" that is so common today. The volume of communication has increased, the importance of a typical message has decreased, and the attention we pay to such a typical message has decreased. However, the aggregate value of all these exchanges has increased.

Sociability was frequently dismissed as idle gossip, and especially in the early days of the telephone, was actively discouraged. For example, a 1909 study of telephone service commissioned by the city of Chicago advocated measured rate service as a way to reduce "useless calls" [JacksonCW]. Yet the most successful communication technologies, the mail and the telephone, reached their full potential only when they embraced sociability and those "useless calls" as their goal [Fischer]. That seemingly idle chit-chat not only provided direct revenues, but it encouraged the diffusion of the corresponding technology, and made it more useful for commercial and other applications. Such social interaction frequently function to grease the wheels of commerce.

This work is based on a more extensive study [Odlyzko3] of the development of the communications infrastructure from the point of view of the user. Usually an infrastructure is noted for being unnoticed; it is simply there, something we come to rely upon, do not have to think much about, and are horribly inconvenienced when it malfunctions. Electricity, water, mail, and the phone are excellent examples. Yet they all took much effort to reach this stage. The key failing of the telegraph was that it never became a true infrastructure component. It was a revolutionary technology, the "Victorian Internet," as one writer has called it [Standage], but it was too cumbersome and too expensive to attract much usage, and in particular never carried much of that "useless" social traffic that pushed the mail and the telephone to their eminent positions.

11. Conclusions

Although social uses are important to the the telephone industry, a glance at Table 1 shows that most of the revenues come from businesses. Household spending on phone service brings in only about a third of the total revenues. (The figures for total revenues, $256 billion in 1997, and consumer spending, $85 billion, come from different sources. It is possible that consumers spend somewhat more, especially for cell phones, than is reported in the $85 billion figure. However, even if one makes the most likely adjustments, it still appears that business spending on telephony is far larger than that of households.) That has been the historical trend, and many communication services, including the phone, were initially devoted almost totally to business uses. Traditionally, commercial users have subsidized residential ones. Sometimes this was done involuntarily, as in higher rates dictated by carriers or by government regulators, and sometimes voluntarily, as in paying for toll-free 800 numbers. It appears probable that similar subsidies will also play a large role on the Internet. (That is also why toll-free numbers for wireless calls may be very important.) We may very well end up with a system in which the largest monetary contribution will come from commercial users, the second largest for households paying for point-to-point communication, and the smallest by the transport component of charges for content.

The value of a broadcast network is usually regarded as proportional to the number of users in it. On the other hand, a point-to-point communication network is often said, by Metcalfe's Law, to have value proportional to the square of the number of member. This then leads to the conclusion that eventually, once a single network like the Internet reaches a large enough size, point-to-point communications will provide much higher value than broadcast. There are some problems with this argument. (See [Odlyzko3] for detailed arguments.) In particular, Metcalfe's Law does not reflect properly several other important factors that go into determining the value of a network. However, the general thrust of the argument and the conclusion are valid. Certainly all the historical evidence cited throughout this work supports the conclusion that connectivity (or point-to-point communication) is what matters the most.

Since connectivity matters the most, and voice usage in cellular systems is low, the main function of 3G wireless systems is likely to be in stimulating more voice calls. Content data services are likely to function primarily as enticements to induce more voice usage. True wireless broadband data access is likely to have to wait until 4G systems arrive, at which time the potential for increased voice usage is likely to be exhausted.

General connectivity is likely to lead to demands for symmetrical links on the Internet. Hence fiber to the home may be needed sooner than is generally expected.

Whether content is king or not has direct relevance for the question of whether the Internet will continue to be an open network, or whether it will be balkanized. If content were to dominate, then the Internet would be primarily a broadcast network. With value proportional to the number of users, there would be few inherent advantages to an open network. The sum of the values of several completely or partially separate networks would be the same as of a unified network. On the other hand, if point-to-point communications were to dominate, and if Metcalfe's Law were to hold, there would be strong economic incentives to a unified network without barriers. This is considered more fully in Section 4 of [Odlyzko3]. The general conclusion there is that even though Metcalfe's Law is not fully valid, the incentives to maintain an open network are likely to be very strong. This will be largely because content is not king, and effective point-to-point communication will demand easy interconnection.

An extreme form of the "content is king" position, but one that is shared by many people, and not just in the content industry, was expressed recently by the head of a major music producer and distributor:

> What would the Internet be without "content?" It would be a valueless collection of silent machines with gray screens. It would be the electronic equivalent of a marine desert - lovely elements, nice colors, no life. It would be nothing.
>
> [Bronfman]

The author of this claim is facing the possible collapse of his business model. Therefore it is natural for him to believe this claim, and to demand (in the rest of the speech [Bronfman]) that the Internet be architected to allow content producers to continue their current mode of operation. However, while one can admire the poetic language of this claim, all the evidence of this paper shows the claim itself is wrong. Content has never been king, it is not king now, and is unlikely to ever be king. The Internet has done quite well without content, and can continue to flourish without it. Content will have a place on the Internet, possibly a substantial place. However, its place will likely be subordinate to that of business and personal communication.

Note: For more detailed arguments, data, and references, see the longer manuscript [Odlyzko3].

Acknowledgements: I thank Frances Cairncross, Bob Frankston, Alan Kotok, Monica Marics, Mike Noll, Hal Varian, and Mark Wolfe for comments and useful information.

References

[Abbate] J. Abbate, *Inventing the Internet*, MIT Press, 1999.

[AdamicH] L. A. Adamic and B. A. Huberman, The nature of markets in the World Wide Web, available at ⟨http://www.parc.xerox.com/spl/groups/dynamics/topics/internetecologies.shtml⟩.

[Baker] S. Baker, Telefónica: Takeover escape artist? It's fending off predators with spin-offs that boost market cap, *Business Week*, April 10, 2000.

[Bronfman] E. Bronfman, Jr., Remarks as prepared for delivery at the Real Conference 2000, San Jose, May 26, 2000, available as a Seagram press release, ⟨www.seagram.com/news/current-press/scl052600b.html⟩.

[CoffmanO1] K. G. Coffman and A. M. Odlyzko, The size and growth rate of the Internet. *First Monday*, Oct. 1998, ⟨http://firstmonday.org/⟩. Also available at ⟨http://www.research.att.com/∼amo⟩.

[CoffmanO2] K. G. Coffman and A. M. Odlyzko, Internet growth: Is there a "Moore's Law" for data traffic?, *Handbook of Massive Data Sets*, J. Abello, P. M. Pardalos, and M. G. C. Resende, eds., Kluwer, 2001, to appear. Available at ⟨http://www.research.att.com/∼amo⟩.

[CTIA] CTIA (Cellular Telecommunications Industry Association), April 11, 2000 press release, "CTIA Reports 1999 Survey Results," available at ⟨http://www.wow-com.com/news/ctiapress/body.cfm?record_id=857⟩.

[Denison] T. S. Denison, The telephone newspaper, p. 640 of *World's Work*, April 1901 edition. Reproduced at ⟨http://www.ipass.net/∼whitetho/part1.htm⟩.

[deSolaP1] I. de Sola Pool, ed., *The Social Impact of the Telephone*, MIT Press, 1977.

[deSolaP2] I. de Sola Pool, *Forecasting the Telephone: A Retrospective Technology Assessment*, Ablex, 1983.

[deSolaPITH] I. de Sola Pool, H. Inose, N. Takasaki, and R. Hurwitz, *Communications Flows: A Census in the United States and Japan*, North-Holland, 1984.

[Douglas] S. J. Douglas, *Inventing American Broadcasting*, Johns Hopkins Univ. Press, 1987

[Ettema] J. S. Ettema, Interactive electronic text in the United States: Can videotext ever go home again?, pp. 105-123 in *Media Use in the Information Age: Emerging Patterns of Adoption and Consumer Use*, J. L. Salvaggio and J. Bryant, eds., Lawrence Erlbaum Associates, 1989.

[Fischer] C. S. Fischer, *America Calling: A Social History of the Telephone to 1940*, Univ. California Press, 1992.

[Garfinkel] S. Garfinkel, *Database Nation: The Death of Privacy in the 21st Century*, O'Reilly & Associates, 2000.

[Greenberg] B. S. Greenberg, Teletext in the United Kingdom: Patterns, attitudes, and behaviors of users, pp. 87-101 in *Media Use in the Information Age: Emerging Patterns of Adoption and Consumer Use*, J. L. Salvaggio and J. Bryant, eds., Lawrence Erlbaum Associates, 1989.

[JacksonCW] D. C. Jackson, W. H. Crumb, and G. W. Wilder, *Report on the Telephone Situation in the City of Chicago; In Respect to Service, Rates, Regulation of Rates, etc.; submitted to The Committee on Gas, Oil and Electric LIght of the City Council of the City of Chicago*, Gunthorp-Warren Printing Co., 1907.

[John] R. R. John, *Spreading the News: The American Postal System from Franklin to Morse*, Harvard Univ. Press, 1995.

[KatzA] J. E. Katz and P. Aspden, A nation of strangers?, *Comm. ACM* 40 (1997), 81-86.

[Klopfenstein] B. Klopfenstein, Problems and potential of forecasting the adoption of new media, pp. 21–41 in *Media Use in the Information Age: Emerging Patterns of Adoption and Consumer Use*, J. L. Salvaggio and J. Bryant, eds., Lawrence Erlbaum Associates, 1989.

[Krause] J. Krause, Global Crossing plans its media play, *The Standard*, March 27, 2000. Available at ⟨http://www.thestandard.com/article/display/0,1151,13209,00.html⟩.

[Lesk] M. Lesk, How much information is there in the world?, 1997 unpublished paper, available at ⟨http://www.lesk.com/mlesk/diglib.html⟩.

[Licklider] J. C. R. Licklider, *Libraries of the Future,* MIT Press, 1965.

[LickliderV] J. C. R. Licklider and A. Vezza, Applications of information technology, *IEEE Proc.* 66 (1978), 1330-1346.

[LymanV] P. Lyman and H. R. Varian, How much information?, available at ⟨http://www.sims.berkeley.edu/how-much-info/⟩.

[MargolisR] M. Margolis and D. Resnick, Third Voice: Vox populi vox Dei, *First Monday,* October 1999, ⟨http://firstmonday.org/issues/issue4_10/margolis/index.html⟩.

[Noll] A. M. Noll, *Highway of Dreams: A Critical Appraisal of the Communications Superhighway,* Lawrence Erlbaum Associates, 1997.

[Odlyzko1] A. M. Odlyzko, The slow evolution of electronic publishing, pp. 4–18 in *Electronic Publishing '97: New Models and Opportunities,* A. J. Meadows and F. Rowland, eds., ICCC Press, 1997. Available at ⟨http://www.research.att.com/∼amo⟩.

[Odlyzko2] A. M. Odlyzko, The Internet and other networks: Utilization rates and their implications. Presented at the 1998 Telecommunications Policy Research Conference. *Information Economics & Policy*, vol. 12 (2000), pp. 341-365. Available at ⟨http://www.research.att.com/∼amo⟩.

[Odlyzko3] A. M. Odlyzko, The history of communications and its implications for the Internet. Available at ⟨http://www.research.att.com/∼amo⟩.

[Oftel] U. K. Office of Telecommunications, Nov. 2000 Market Information Update, available at ⟨http://www.oftel.gov.uk/market/miu1100.pdf⟩.

[Pew] Pew Internet Project report, The holidays online: Emails and e-greetings outpace e-commerce, Dec. 31, 2000. Available at ⟨http://www.pewinternet.org/reports/toc.asp?Report=29⟩.

[Schlender] B. Schlender, Sony plays to win, *Fortune,* May 1, 2000, pp. 142+. Available at ⟨http://www.fortune.com/fortune/2000/05/01/mak.html⟩.

[Smulyan] S. Smulyan, *Selling Radio: The Commercialization of American Broadcasting, 1920-1934*, Smithsonian Institution Press, 1994.

[StArnaud] B. St. Arnaud, The future of the Internet is NOT multimedia, *Network World*, Nov. 1997. Available at ⟨http://tweetie.canarie.ca/∼bstarn/publications.html⟩.

[Standage] T. Standage, *The Victorian Internet: The Remarkable Story of the Telegraph and the Nineteenth Century's On-line Pioneers,* Walker, 1998.

[USDOC] U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States 1999,* 1999. Available online at ⟨http://www.census.gov/prod/www/statistical-abstract-us.html⟩.

[Winston] B. Winston, *Media Technology and Society: A History: From the Telegraph to the Internet*, Routledge, 1998.