Telecom dogmas and spectrum allocations

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Abstract. A substantial spectrum reallocation is called for. The current system is extraordinarily inefficient and inadequate for the challenge of stimulating innovative new services and business models. It also perpetuates the traditional and deeply flawed bias in favor of content instead of connectivity.

A proper spectrum reallocation would promote new services directly, and would speed up the developing restructuring of telecommunications. In addition, it would also help disprove many myths that are hobbling this vital industry.

1 Introduction

The current spectrum allocation system is deeply flawed. Even if it was appropriate decades ago, given the primitive wireless technologies that were available at that time, it is obsolete. The inefficiencies of our current system have been documented extensively, in particular in the reports by the New America Foundation's Spectrum Policy Program [12]. This note will not review them, and instead will discuss some high level issues related to current and prospective uses of spectrum. The perspective will be based on history and economics. Although technology has changed dramatically over the centuries, economics, psychology, and sociology have not, and many of the issues we face today are fundamentally the same ones faced by society in the past when faced with some previous novel technologies.

A key issue is the degree of control that service providers should have. To what extent should their technology or business model choices be constrained by government? There is vigorous debate on this topic, and it largely repeats earlier debates for other technologies. For example, in the 19th century, railroads were the most prominent and most disruptive new technology, and there were long debates on what the role of government should be in their construction. Governments' powers of eminent domain were always used to enable acquisition of rights of way. Although there was controversy on this issue, the general consensus was that private contracting with landowners could not be relied upon to obtain the agreement of all affected landowners in a timely and economically feasible manner. Beyond the use of eminent domain, there was less agreement. Financing was almost entirely by private investors in Britain, whereas in the U.S. there were huge implicit or explicit subsidies by governments to railroads that were privately built and operated. Technology choices were left almost completely to the operators. For example, in Britain (p. 54 of [5]),

> Parliament wisely refrained from binding the first railway projectors to adopt any specified form of rail. Whether a plank of wood or an iron plate should be used; whether the rail should be laid on stone or on wooden sleepers, should be flanged or smooth, should be flush with the ground, or sunk, or project above the ground, whether the wheels should be cogged or toothed, fitting into the rail as they revolved, to prevent skidding, or should offer a plain surface, guided by the grooved rail:–these were questions with which Parliament did not meddle. Each of these plans, however, had it advocates, and was in turn adopted.

However, later on, the British Parliament did intervene to standardize rail gauges. A similar standardization was accomplished in the U.S. largely through voluntary cooperation, although under intense pressure from private shippers.

While governments in both Britain and the U.S. refrained from heavy involvement in technology choices, they all had an intense interest in pricing, and attempted to control price discrimination. They were rather effective with canals and turnpikes, but largely failed with railroads (and the failure led to the introduction of strong regulation at the end of the 19th century). The story is told briefly (with extensive references) in [24]. The point is that the attempts to control pricing were a compromise between two demands. One was the perceived need to provide funds for infrastructure construction and operation through price discrimination. The other was the desire to encourage enterprise, which calls for preventing service providers from appropriating the entire consumer surplus that technological or business innovation creates.

Today, the key discussions about broadband are really about the same issue. Should service providers be given complete control over their networks in order to get them to deploy broadband? Or should they be pushed towards a "dumb pipes" model that maximizes innovation at the edges? There is increasing realization that fiber-to-the-home (FTTH) is not feasible economically in the near future. There is also concern whether the duopoly of cable TV operators and ILECs can be trusted to deploy the needed infrastructure and provide associated services, and if so, on what terms. (If FTTH were to be the future, those concerns would be even greater, since for that technology, natural monopoly does appear to apply. But even competition between cable modems and DSL might not be sufficiently vigorous, since in the past the ILECs and the cable companies have refrained from competing.) The dynamics of financial markets (and, a key precondition, the developments in technology that lead to a convergence in the services that different networks can offer) may very well lead to vigorous competition between cable and ILECs without any external intervention [23]. But that is not certain, since natural monopoly issues might lead to either instability that would collapse into monopoly or an uneasy but stable duopoly. Wireless can play a major role in stimulating such competition, both indirectly (through voice traffic migration to wireless) and directly, by providing an alternative broadband link, and thus leading to real facilities based competition.

Right now, voice traffic, which is where most of the money continues to come from, is just beginning to move from wireline to wireless transmission. In the long run, we should expect almost all voice to be carried by wireless links (at least for the first segment, as fiber will continue to be used for long haul and even in metro areas, where traffic can be

aggregated sufficiently). The move of voice to wireless transmission is likely to force the ILECs to put more effort into providing broadband connectivity, since bandwidth is the one area where they will continue to have an unquestioned technical advantage over wireless.

Thus there is some likelihood that the growth of wireless voice traffic will indirectly stimulate deployment of wireline broadband. In addition, broadband wireless access to the Internet is increasingly proving itself to be feasible, as the technology improves faster than residential users' demand for bandwidth. That is extremely encouraging, since scaling properties of wireless deployments are far more favorable than any wireline technology. The main costs tend to depend primarily on the number of subscribers, and not on the number of households in the area. Therefore it is feasible to provide service in areas with low density of subscribers, and also to have multiple competing operators. Hence even if wireless does not become the dominant technology for providing broadband access to the Internet, it could still provide an important check on any predatory practices of the wireline broadband providers.

Could wireless further destabilize the telecom industry and bring it crashing down? Much of the regulatory action of the 20th century was directed towards building an elaborate system of taxes and cross-subsidies to provide universal coverage. Is the resulting universal connectivity in danger? Most likely not. Total telecom spending, even when measured as a fraction of GDP, has increased substantially over the last few decades, and it already supports copper, coax, and wireless access for the overwhelming majority of the population. At the same time, technology has been lowering the costs of providing all telecom services. Stock market valuations in the telecom sector are still in most cases far ahead of replacement values [23], and so apparently anticipate monopoly profits. Under these conditions, the best public policy would be to err on the side of encouraging competition and innovation, and not of protecting existing carriers. That has worked well in South Korea [11], and should work in the U.S. as well. Even when service providers run into financial difficulties, that is unlikely to lead to service interruptions. Telecommmunications is a high fixed cost and low marginal cost business, and so it is profitable to continue providing service, even if it does not pay to expand it. We have seen this with Internet backbone backbone providers recently, very few of which were liquidated. The same phenomenon occurred in the 19th century when canals faced competition from railroads. Canals responded by lowering their tolls, but for the most part continued in business for a long time. (In Britain, the peak in the volume of freight carried on canals was close to 1900.) Thus the main danger that competition poses is to shareowners and bondholders, who will likely see much of their anticipated profits and the resulting elevated valuations disappear.

Promoting diffusion of general broadband access is desirable, and can be facilitated by promoting wireless communication. But there are two even more important reasons for advancing wireless and in particular for making more spectrum available for it. One is that mobility, which is what wireless provides, is extremely valuable, and offers the promise of major boosts to economic productivity. The other one is that the telecom industry is shackled by a set of misleading myths. These myths, the main ones to be described in somewhat more detail in Section 4, are mutually reinforcing, making them that much

harder to shed. They impede the necessary restructuring of the industry, to be discussed in Section 3. In very rough terms, and using an analogy with the computer industry, the telecom sector appears to be pining for and planning to restore the mainframe to its dominant form, instead of adjusting to the distributed computing era. Greater promotion of wireless connectivity, especially in ways that enable local innovation, would serve to demonstrate what users really need from telecom, and speed up the evolution of this sector. (This has to be done carefully, since current cellular carriers are addicted to closed architectures, so giving them control of all additional spectrum meant for communication would play an inhibiting role.)

For wireless to fulfill its promise, more spectrum for connectivity services is called for. Yes, technology is advancing, but there are limits to what can be done with it, especially at reasonable cost and in the near term. In particular, low frequencies are and for the foreseeable future will remain far more desirable for connectivity than high frequencies. Far too much of this valuable spectrum has been assigned to broadcasting, the result of a confluence of technologies available many decades ago and one of the key myths to be discussed later, namely that content is king. Moreover, much of it is simply not being used. It is time to redirect it more productively, towards connectivity services.

2 Licensed versus license-free spectrum

The inefficiency of the current spectrum allocations is documented well at [12]. For much of the spectrum, the government prescribes not just the technology, but even the applications that can use it. Most of the spectrum is idle, as the envisaged applications have not developed as anticipated. (In particular, much of the spectrum set aside for broadcasting is not being used.) Thus a major reform is called for. Unfortunately, given how our political system operates, license holders, commercial as well as non-profit, will be next to impossible to force to give them up, even if they are not using them productively. The only spectrum that there is any hope of reclaiming any time soon is that given to broadcasters as part of the digital transition, since it was given with explicit mandate of returning it back to the public. The political obstacles that exist in the way of reclaiming even those frequency bands demonstrate how hard it will be to rationalize the entire system by simple government reallocation whenever there are any actual users. Hence it might be best to give current license holders formal ownership (or at least a long-term lease) of the spectrum they occupy, and allow them to trade it freely. That would allow other enterprises with more productive uses for the spectrum to take over. If this is done, the amount of licensed spectrum available for connectivity services will grow substantially.

In addition to the liberalization on use and trading of licensed spectrum, there are substantial ranges that the government is hoarding right now, those reserved for broadcasting that are not used, as well as those bands that hopefully can be reclaimed soon from the broadcasters as part of the digital transition. The ideal solution would be to devote all of it to license-free operation. That is where the greatest amount of innovation is taking place right now. In particular, it encourages local initiative, which is less encumbered by the misleading telecom myths to be discussed in Section 4. Now license-free spectrum may not work out as well on a large scale as its advocates suggest. (In particular, just consider the

problem of spam, viruses, and worms. It is hard to cope with in the wireline environment, and would likely be far more difficult to cope with in the wireless one. Centralized control of spectrum bands can be helpful there. As we know from extensive experience, in the wireline world, an ISP telling a customer that his computer won't be allowed to send or receive anything until it is cleaned up is far more effective than asking that customer "Would you be so kind as to get rid of that malware on your machine, so it will no longer launch denial of service attacks against that poor chap in Malawi.") However, it is worth experimenting with. Even if license-free operations do run into scaling problems, that would only enhance the value of licensed spectrum.

3 Telecom restructuring

Much of the current turmoil and distress in the telecom sector is the result of the overinvestment and malinvestment of the bubble years. In addition, there is a fundamental and painful restructuring that is taking place, stimulated by advances in technology. In particular, the traditional long haul sector is shrinking, so that the consumer long distance businesses of AT&T, MCI, and Sprint, while still cash cows, are in a state of terminal decline. (And the best hope for those three companies would probably be to combine and provide an alternative to ILECs as service providers to large enterprises.) The basic problem for these carriers as well as other national Internet backbone providers is that technology has reduced the costs of long haul transport to almost negligible levels. As one example, already cited in [24], the transatlantic cable constructed a few years ago by 360networks for $850 million was recently bought by an investor for $18 million [3]. It costs about $10 million per year to run, and at time of sale had lit capacity of 192 Gb/s, which was sufficient at that time to carry the entire transatlantic Internet traffic. (Note that even if one had to pay $850 million for that network, that would still be relatively inexpensive relative to the service it can provide.) Other examples are cited in [22, 23]. They imply that the core transport service for all of the U.S. can be provided for less than 1% of the $300 billion that this country spends on telecommunications each year.

The core is thus simply not a problem any more, unless someone were able to monopolize the long haul fiber capacity. (And even in that case it would not be prohibitively expensive to lay down new fiber.) This is a result of general progress of technology and the overinvestment of the bubble, which produced a glut of both fiber in the ground and of advanced transmission and switching technologies. (Therefore although the telecom bubble was extremely wasteful, it did produce some good.) Thus in spite of concerns about viability of the core, and attempts to provide differentiated services in it in order to make it profitable, it is likely that the backbones will continue to evolve towards providing undifferentiated high quality transmission primarily through overengineering. That is how the costs of the entire telecom sector can be minimized. Core transport will be a commodity business, possibly quite profitable after some consolidation, but a small one.

The restructuring of the telecom industry can be compared to what happened in transportation over the 20th century. In 1900, railroad revenues in the U.S. were about 8% of GDP. By 2000, while the volume of freight transported by rail grew many fold, railroad

revenues were only about 0.35% of GDP. It was the edge transport that grew, as it evolved from horse-drawn wagons towards cars and trucks.

While the core of the network has been hollowing out, costs have been migrating towards the edges. It is a myth that the Internet is a low cost network. With proper accounting for all the ancillary costs, especially those of hapless (and helpless) end users who are forced to do system administration work [13, 14], one finds that the overall costs are very high, and most of them are associated with handling the complexity of the system. (As just one very small and very recent example of this trend, the president of Boingo, a Wi-Fi aggregator, stated recently that the "main cost is its 70 employees" [25].)

At the edges, we are already witnessing the rise of an extremely heterogeneous system. Some (large) customers are buying their own fiber, others are outsourcing their entire communications operations. The traditional idea of a large, vertically integrated service provider delivering essentially the same "plain old telephone service" (POTS) to everybody is less and less relevant, as the customer demands diverge. Some are happy with POTS, others just with a cell phone, while yet others need OC3s with all sorts of bells and whistles.

The historic trend in telecommunications has been of revenues growing faster than the economy as a whole [17], at least over long periods of time, and this trend is likely to resume as we continue the evolution towards an economy based on information. But who will provide the services that collect these increasing revenues is to be determined. We should expect a lot of disintermediation and reintermediation. Telecommunications is converging with content delivery as well as with computing, and traditional carriers may not be well positioned to profit from the transition. They have the technology and marketplace position to do well. Unfortunately culturally they lag, as they are misled by a collection of mutually reinforcing and false myths.

4 Misleading telecom dogmas

This section discusses briefly some of the many misleading myths that shackle the telecom industry. What is most amazing is that many of the misleading myths that shackle the telecom industry have been recurring in history, starting with postal systems centuries ago, in spite of plentiful evidence against them. It appears that often it takes hard experience for service providers to discover the right solutions. Fortunately that can happen. As an example, it does appear that as a result of its leadership in broadband as well as cellular usage, South Korea has unlearned some of these myths. For example, according to [2], the myths that content is king and that killer apps are required no longer dominate:

> "The killer application of the Internet is speed," said Lee Yong Kyung, the chief executive of the KT Corporation, formerly known as Korea Telecom, which controls nearly half of the country's broadband market. "The money is in the pipes."

On the other hand, Korea still appears to be in thrall to the myth of streaming real-time multimedia traffic dominating.

4.1 Carriers can develop innovative new services

There is no serious evidence to support this myth. In spite of many attempts, the established service providers and their suppliers have an abysmal record in innovation in user services. They have done very well in terms of improving the basic transport technologies, as with dense wavelength division multiplexing (DWDM), erbium-doped fiber amplifiers (EDFA), DSL, and cellular (which was adding mobility to the traditional voice service). But in terms of services as perceived by users or that require user involvement, the record is dismal. ATM, QoS, RSVP, multicasting, congestion pricing, active networks, WAP, and 3G, have all been duds, not because they failed to work, but because they failed to satisfy user demands. The real "killer apps," such as email, the Web, browsers, search engines, IM, and Napster, have all come from users. Is there any reason to expect the future to be any different?

If anything, we should expect an even greater fraction of innovations to come from users at the edges of the network. We are experiencing several types of convergence, of computing and communications, of content and connectivity, and so on. Hence the variety of services will be growing, and the ranks of potential creators of those services will also be growing. It will require ever more knowledge of what users need to take advantage of the growing opportunities, and we can't expect centralized organizations to be able to do it. The only way to prevent these users from contributing a lion's share of innovation would be to impose a new network architecture that limits what users can do with it, something like Minitel. That is not likely to happen.

A fruitful analogy might be with the computer industry. The mainframe manufacturers used to provide not just the hardware and the operating system, but also much of the application software (at least in the early days). But now, after a painful restructuring that destroyed some of the old mainframe companies, and seriously damaged even IBM, forcing it to a painful reorientation, we have a very healthy computer industry that is based on horizontal layers. The most successful player in the new structure is Microsoft. Yet Microsoft attained its position not by innovating in individual services, but by providing a platform for others to innovate on.

The most promising role for telecom carriers would be to imitate Microsoft, and provide communication platforms. They should enable innovation by users, watch what succeeds, and then incorporate what is most successful and is appropriate into their platforms.

4.2 Content is king

One of the oldest, most wildly held, and most damaging myths is that content is king. Content (defined here as material prepared by professionals for consumption by large audiences, in particular movies, recorded music, and professional sports team play) is a large and prosperous business. However, it has never been as large or as important as connectivity, person-to-person communication. For detailed arguments and supporting data, see [17, 18]. In addition, in Table 1 we see estimates for how much people value different types of communication. (Estimates are rough, and in all cases but for SMS, are based on typical U.S. usage and price.) Basic person-to-person connectivity dominates. That is how it has

Table 1. Value of bits: Cost per megabyte of various services.

service	typical monthly bill	revenue per MB
cable	$40	$0.00012
broadband Internet	$50	$0.025
phone	$70	$0.08
dial Internet	$20	$0.33
cell phone	$50	$3.50
SMS		$3000

been historically. New telecommunications services, when first placed into non-government service, were typically dominated by commercial traffic. As an early example, we have the following message from about 2000 B.C from two partners in Assur to a correspondent in Anatolia (p. 30 of [4]):

> Thirty years ago you left the city of Assur. You have never made a deposit since, and we have not recovered one shekel of silver from you, but we have never made you feel bad about this. Our tablets have been going to you with caravan after caravan, but no report from you has ever come here.

The motive is universal. Somebody owes you something, so as long as there is hope of collecting, you try out to reach him.

Once a service becomes inexpensive enough, social uses begin to play a major role. We have an example in a message from a teenager near Alexandria, Egypt (then a part of the Roman Empire) to his father around 200 A.D. (p. 225 of [4]):

> A fine thing you did! You didn't take me with you to the city! If you don't want to take me with you to Alexandria, I won't write you a letter, I won't talk to you, I won't say Hello to you even. If you go to Alexandria [*sc.* without me], I won't shake hands with you or greet you ever again after this. If you don't want to take me, that's what will happen. ... A fine thing you did, all right. Big gifts you sent me - chicken feed! They played a trick on me there, the 12th, the day you sailed. Send for me, I beg you. If you don't, I won't eat, I won't drink. There!

Such correspondence tends to evoke snickers (just as SMS messages between teenagers do today). But to teenagers, whether in 200 A.D. or today, such messages do matter a lot. In fact, the general disdain for what is often called gossip has repeatedly misled decision makers. Not only is there a lot of money in carrying gossip, but gossip plays a crucial role in all human interactions [9].

The myth of content as king has repeatedly led telecom firms to waste huge amounts of money trying to get into the content business. Yet providing pipes for connectivity has always brought much more revenue than content distribution. As just one modern example, note that in the U.S. a broadband subscriber of a cable network typically pays as much for his Internet connection, which uses just one channel, as from all the 100+ channels of entertainment.

Even more seriously, the myth of content as king has led to essentially all residential broadband links being designed asymmetrically, with greater capacity to the household

than away from it. The underlying assumption was that the main purpose of the link was going to be to download content. There are signs that the telecom industry (especially in Korea) is beginning to recognize the mistake, but it is a slow process.

The myth of content as king is also behind much of the movement to enact harmfully restrictive copyright laws.

4.3 Voice is irrelevant

Voice is still what provides well over 70% of telecom service revenues. In particular, the real telecom success story of the 1990s, whether measured in terms of revenue growth or number of subscribers, was in wireless voice, not on the Internet. In their infatuation with data and especially with content, carriers appear to have given up on doing anything innovative with voice. Now it is true that eventually we will have a broadband pipes, whether wired or wireless, and voice will be just another service delivered over them at low or even zero cost. This will be similar to what has happened with email, which has been and continues to be the killer app of the Internet. But note that the importance of email is understood by ISPs, and it continues to get enhanced. Not so with voice. And yet there is much more that can be done with voice. In addition to various forms of unified messaging, as well as voice recognition, in a broadband environment one can offer higher quality voice. Many users of Skype, the P2P VoIP service, have noticed that frequently (when the transmission path is uncongested), they get considerably higher voice quality than with conventional "toll quality" wireline voice. And they like it. Yet the industry appears to be oblivious to the opportunities this offers.

The neglect of opportunities for improving wireline voice is surprising, but only slightly so, since the gains there would not be huge. The lack of attention to wireless voice, on the other hand, is just astounding. For the last decade the wireless industry has been mesmerized by the "content is king" myth, and has been developing 3G for content delivery. Yet 3G was initially planned primarily for voice, and that is where the opportunities are, as has been clear for years [18, 20]. In almost all countries wireless carries at most a third or a quarter of all voice, so opportunities for fixed-mobile substitution are great. Even very simple features, such as toll-free wireless calling, are not being offered. The greatest neglected opportunity, though, is in the wireless voice quality area. The current quality of cellular voice is basically abysmal, just barely tolerable. With more bandwidth, which is what 3G provides (as well as with better coding schemes), one can offer far better fidelity. Perhaps even more important, while there continues to be a shortage of spectrum, one can offer several levels of quality at different prices. This would segment the market, something that carriers have been desperately trying to do with content delivery.

There are some signs that the wireless industry is beginning to realize that voice will be the main application of 3G [1]. But this recognition is late and slow. This is very strange, because voice is an extremely important human method of communication. We all know that "one picture is worth a thousand words." But that is not quite right. In my public talks, I often ask the audience what their reaction would have been if, shortly before the lecture, they were told that there would be no slides or other graphics aids available, due to some technical or safety problems. How many would decide not to attend? Usually just a

handful raise their hands. I then ask, suppose instead they were told ahead of time that for some strange reason, slides, flip charts, and so on would be available, but neither I nor they could say a word. How many would still come? Usually just a handful, and sometimes not a single hand goes up. Voice is still the main method for human communication. Pictures, photos, and video are all very important, but usually not by themselves. What does seem to be true is that (p. 225 of [26]):

> One picture is worth a thousand words, provided one uses another thousand words to justify the picture.

The importance of voice leads to the relative unattractiveness of videotelephony. It has been a disappointment time after time for over three decades, starting with the Bell System Picturephone. This failure is still only partially understood. Some of the reasons for it include the difficulty of doing email on the side when talking on camera and the necessity to dress up. But whatever the reasons, videotelephony is not a killer app, and we should expect slow growth in it. Videoconferencing is likely to be accepted more widely, but is not likely to generate much traffic.

Videoconferencing leads to one of the minor and relatively innocuous myths of telecom. While telecommuting and videoconferencing are likely to grow, that will not reduce road congestion. There is this strangely persistent myth (which I have traced back to the 1830s, and its origins are surely even earlier) that telecommunications and transportation are substitutes for each other. They are not, and are in fact positively correlated. Hence we should expect growth of travel at the same time as telecom usage is booming.

4.4 Streaming real-time multimedia traffic will dominate

Videotelephony, videoconferencing, and audio and video delivery have been the dreams of the telecom industry for decades. As a result, this area (including researchers as well as business people) has become mesmerized by the prospects of streaming real-time multimedia traffic, and continues to expect such traffic to dominate the networks. This expectation was reinforced by the fact that until a few years ago, the only way to deliver audio and video over a telecom network was by streaming. But now we have plentiful magnetic storage. Therefore, as had been predicted a long time ago by Negroponte, Gilder, and others, it makes much more sense to deliver content (which is, after all, prepared by experts for wide consumption) as files for local storage, replay, and transfer. (Hardly any content in this definition requires the synchronicity of voice or videotelephony.)

The future of multimedia traffic is not just in file transfers, but also in faster-than-real-time file transfers. This seems to be almost completely missed by the telecom industry. I have started asking audiences at my telecom-related lectures whether they see any sense for carriers or consumers in faster-than-real-time multimedia transmission. Typically at most 10% raise their hands in the affirmative. Yet such transfers already dominate many networks. P2P music files are typically transmitted at 500 Kbps or faster, while the underlying MP3 encoding is usually something like 100-200 Kbps. Moreover, in U.S. backbones (and we do have some data, for example for Sprint), P2P file transfers are far bigger, by factors of 5 to 10 and higher, than streaming. (In Korea, the dominance of P2P file transfers

over streaming appears to be even greater, [28].) So the phenomenon of faster-than-real-time transmission has already become dominant, but the industry is not aware of it, and certainly does not understand it.

What are the advantages of faster-than-real-time transmission of multimedia? There are a variety of them, discussed in many of my papers. Among others, such transmission makes QoS unnecessary, it caters to human impatience, it allows natural behavior, such as quick download followed by a quick transfer to a portable device to take on a trip, and it allows for a natural progression, starting with slower-than-real-time when you don't have the bandwidth, and then moving up to faster-than-real-time. But the industry is still concentrating on developing technologies for streaming real-time delivery.

The telecom industry should really embrace the prospect of faster-than-real-time file transfers, as it offers the prospect of an unending cycle of upgrades, as people get more and more impatient, and files get larger. Instead, this industry is worried about hitting a brick wall. This appears true even in Korea. An American expert on streaming multimedia technology who spent the summer of 2003 in South Korea, working with researchers there, reports that even the Koreans see no reason for ever going much beyond 50 Mbps to the home. After all, that would provide for several HDTV channels, and all the Web surfing and email anyone could want. But with faster-than-real-time file transfers, it is easy to envisage demand arising for bigger pipes.

4.5 There is an urgent need for new "killer apps"

One can detect a sense of desperation in the frequent calls for a new telecom "killer app," to produce more money and excitement. Yet one of the key lessons of the Internet is that with control in the hands of users, demand continues to grow vigorously. U.S. Internet backbone traffic grew very close to 100% a year throughout the 1990s and early 2000s, with the exception of that manic growth period of 1995-96, when it grew about 1,000% a year [6–8, 22]. As of this writing, in June 2004, that growth still seems to be around 70% a year, while in Korea (which experienced its own brief period of about 1,000% annual growth around 2000, when broadband was deployed very widely in a short period of time) growth seems to be close to 100% a year [28]. One of the key historical lessons of [6, 7] is that in places that were already using the Internet widely in the early 1990s (primarily universities and research institutes), growth rates were not much affected even by the arrival of such "killer apps" as the browser and Napster. (Furthermore, even in the absence of any bandwidth constraints, traffic seldom more than doubled on an annual basis in such places.) Information technology still has a long way to do in terms of diffusing through society, and that will continue generating additional traffic. This is not to argue that there won't be any new applications that will be called "killer apps," or that one should not look for them, but the general conclusion is that there is no need to rely on their discovery.

4.6 Death of distance

The Internet is often cited for erasing the gaps created by physical distance. But that is a misleading notion. While the Internet traffic so far has been rather independent of distance, that is likely to change substantially, to fall into the pattern of other communication

services, which have been and continue to be primarily local [6, 17]. One sign of that is in reports from Korea that less than 5% of their Internet traffic goes outside that country. Many other, more general, examples are cited in [17] (such as an investment bank moving its office from San Francisco to Menlo Park to be closer to Silicon Valley) and [27]. This has a variety of implications, for overseas outsourcing, for example.

In general, the interplay between locality and globalization is a complicated one. But while long haul transport over fiber is pretty much a solved problem, there is much more to be done locally. That is why WiFi is booming, not necessarily as a paid service, but for improving local communications, whether within homes, or hospitals, or factories. With convergence of consumer electronics, business information technology, telecommunications, and content, the action will be at the edges, in homes and businesses, melding all these elements together. It will be local communication that will need to provided in profusion, in order to allow for easy implementations of new services.

4.7 QoS and measured rates

Some of the most persistent myths of the telecom industry concern the claimed need for QoS and measured rates. They are strongly related to the other myths discussed above. If the majority of traffic were to consist of streaming real-time video carrying movies for human viewing, we could expect traffic to be nicely predictable, and design networks along the lines of the old voice network. Then QoS and measured rates would be appropriate. But that is not the future (nor the present). I have extensive discussions of these topics in earlier papers [13, 15–17, 19, 23, 24] and will not attempt to summarize them here. Let me just mention a few factors. One is that the telecom industry does not appreciate the need to encourage usage. Technology is advancing, so bandwidth is growing, and the service providers that will win will be the ones who teach their customers how to use the increasing capacity of their links. (Data such as that in [10], reporting a slight decline in average traffic per user in a campus wireless network, should be a danger flag.) And nothing helps whet the appetite for bandwidth as much as flat rates and not having to worry about priorities and the like.

The final point that the telecom industry is not paying enough attention to is that complexity is the main obstacle. Deployments of new technologies (such as WiFi in enterprise settings) are gated by the problems that arise in deployment and operation much less than by hardware costs. And introducing QoS and other complications only makes this situation worse. Congestion is far easier and cheaper to solve by installing new capacity than by introducing QoS. (An exception is the wireless area, as noted in [13, 16], for example, where there will continue to be much less capacity than in the connected wireline links, requiring some forms of QoS.) There should be a strong bias in favor of simplicity. As one example, this paper is being written in June 2004, a few days after the release of the report of the 9/11 commission. One of the interesting items in it was that on the morning of that disaster, President Bush at one point had to call Vice President Cheney on a cell phone. There was no shortage of bandwidth on the government circuits, but the complexity of the system (and the confusion of the moment) made it impossible for these two leaders to communicate using those secure channels.

The Bush-Cheney cell call is likely to lead to increased effort to introduce a prioritization scheme for cellular, similar to what exists in the wireline environment. But a much preferable solution would be to something far simpler. If the cellular carriers introduce differentiated voice quality, as suggested in the discussion of the myth that voice is irrelevant, then in cases of emergencies, when traffic spikes up, they could then dramatically increase capacity by pushing all users to the lowest quality level. The decreased quality would surely be much more acceptable to most than having their calls blocked. This would provide a simple solution that would likely be far more effective and less expensive than the conventional prioritization one.

5 Conclusions

The general conclusion is that the telecom industry is stuck in a rut that is largely of its own making. There are far too many dogmas that are leading it astray. Expanding the spectrum that is available for connectivity, as opposed to broadcast, would not only respond to the urgent need for local mobility in communications, but would indirectly aid the whole sector by demonstrating what it is that is truly needed.

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