7-2007

Bringing Broadband to Unserved Communities

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THE HAMILTON PROJECT

Advancing Opportunity, Prosperity and Growth

DISCUSSION PAPER 2008-10 JULY 2008

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The Brookings Institution

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NOTE: This discussion paper is a proposal from the author. As emphasized in The Hamilton Project's original strategy paper, the Project was designed in part to provide a forum for leading thinkers across the nation to put forward innovative and potentially important economic policy ideas that share the Project's broad goals of promoting economic growth, broad-based participation in growth, and economic security. The authors are invited to express their own ideas in discussion papers, whether or not the Project's staff or advisory council agrees with the specific proposals. This discussion paper is offered in that spirit.

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JULY 2008

Abstract

Roughly one-third of households in rural America cannot subscribe to broadband Internet services at any price. This puts many rural communities at a disadvantage with respect to economic growth, job creation, educational opportunities, health care information, commerce, and more. Internet users in urban areas are also adversely affected by the exclusion of so many rural households. For example, e-commerce merchants can attract fewer customers, online universities can attract fewer students, and users of e-mail, Internet telephony, and videoconferencing can communicate with fewer friends and business associates. Government can facilitate the expansion of broadband infrastructure into unserved communities through a suite of interrelated policies. Appropriate changes in spectrum policy would reduce the cost of building new broadband wireless systems in rural areas. These potential new wireless providers could then compete with existing telephone, cable, and cellular companies and other organizations for the obligation to bring broadband to an unserved community in return for a one-time subsidy. Defining this obligation in a highly flexible form and making it tradable on an open market would minimize the cost of infrastructure deployment and thereby reduce the subsidies needed. Attaching very lightweight restrictions on subsidy recipients could protect consumers from monopoly providers that might be tempted to limit their customers' choice of content or applications. Allowing and encouraging local government agencies to play an active role could encourage providers to deploy infrastructure by guaranteeing future revenues and ensuring access to critical resources. Collecting better information on availability of broadband services nationwide would allow both policymakers and potential service providers to better identify the communities that need service. Together, these mutually reinforcing policy reforms would allow government to move the United States closer to the goal of universal access to broadband Internet by harnessing market forces without competing with market forces.

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1. Introduction

The "digital divide" is sometimes discussed as if it were primarily an Internet disparity between rich and poor. In reality, many residents of rural communities find themselves on the wrong side of the digital divide, regardless of their income. Indeed, penetration of high-speed Internet, otherwise known as broadband, among those in rural areas is almost identical to penetration of broadband among those with total household incomes under $30,000 (Horrigan and Smith 2007).

The Federal Communications Commission (FCC) currently defines broadband as 768 Kb/s or greater, which includes cable modem, digital subscriber line (DSL), and many wireless services, but not dial-up modem service. While most city-dwellers can get a broadband connection simply by calling a local provider, there are many rural communities and perhaps a third of rural households that do not have that option. Ironically, the nation that invented the Internet is falling behind in its ability to make the Internet available to all of its citizens. Thanks to new technology, this rural-urban disparity may now grow worse; in many big cities, today's broadband services are being replaced by all-fiber networks that give each consumer a ten-fold or more increase in capacity, while many smaller towns wait for their first broadband deployment.

It is important to bring broadband access to unserved communities for a number of reasons. Especially in otherwise isolated areas, high-speed Internet access puts people in contact with resources that are physically out of reach, improving individual welfare by increasing access to educational, medical, commercial, and professional resources. Positive externalities resulting from broadband such as increased economic growth and improved government services also improve the community's overall welfare, benefiting both Internet users and nonusers. Increasing access in unserved communities also has benefits on a national level because network effects ensure that the more people that have high-speed Internet, the more useful it becomes. Conversely, network effects also mean those without broadband access are increasingly disadvantaged. As broadband becomes available to the majority of households, online content, applications, and services will increasingly become designed for broadband users. Companies and government agencies, who will assume that most individuals have high-speed Internet access, will be less inclined to cater to those who do not.

Technological diversity is particularly important as we focus on unserved regions, which are predominantly rural. Very different technologies may be best suited for providing Internet service in rural and urban areas. In particular, wireless technology tends to be more cost effective when bringing Internet services to more sparsely populated areas. Thus, policymakers must take steps to facilitate the use of wireless technology, which makes spectrum management policy an essential part of bringing Internet to unserved communities. At the same time, if U.S. policymakers choose to make targeted subsidies available in addition to spectrum (the range of electromagnetic waves by which wireless signals are carried), they must be careful to make those subsidies available for whatever current or future technology is most cost effective. Maintaining this technology neutrality is more difficult than first appears, as will be discussed in §4.2. Policies that are commonly proposed implicitly favor one technology over another.

This paper presents three complementary policy changes that could facilitate the leap into broadband connectivity for unserved communities, each of which can be advanced in parallel. First, policymakers should make more spectrum available, and they should make the regulatory and technical requirements associated with this spectrum appropriate for broadband systems that serve sparsely populated areas. This could make the deployment of an entirely new broadband system cost effective in regions where it is too costly today. Examples include making some part of the "white spaces" in the television (TV) band available in a form that is appropriate for low-cost broadband, and taking concrete steps toward making government spectrum available to commercial users, where those commercial users pay the transition costs.

Second, policymakers should allow these new wireless providers, along with established telephone and cable companies and others, to bid in a competitive auction that would obligate the winner to make broadband services available in return for a one-time subsidy. Unlike other policy proposals, this obligation is designed to be highly flexible and fully tradable, allowing each provider to build a portfolio of obligations through market mechanisms that can be achieved in a highly cost-effective manner consistent with the provider's technology and evolving business plan.

Finally, local governments should be brought in to play a greater role in universal service policy. Current laws that artificially limit a municipality's role in broadband deployment would be eliminated, so decisions can be made by elected officials who are directly accountable to local voters. Beyond this, before the auctions described above take place, local governments could commit to becoming customers of the resulting systems and to make valuable resources available to auction winners.

Given the many recent calls for a comprehensive Internet policy for the United States, it should be noted that this paper focuses exclusively on promoting universal access to rudimentary broadband service, where *access* means the service is available to those households that want to subscribe. A comprehensive Internet policy might seek to advance universal service by increasing the number of Internet users, rather than just by increasing the number of users with access. A comprehensive policy might also seek to increase the capacity and quality of services that are available by encouraging deployment of more advanced technology, and to increase the extent of competition in the marketplace. These are all desirable outcomes for the nation as a whole, although they are largely beyond the scope of this paper. For communities without broadband infrastructure, access is the immediate concern. After expanding access, one can later assess whether separate policies are needed to deal with affordability.

2. Current State of U.S. Broadband Infrastructure

This section reviews the state of services that are widely accepted as "broadband," such as cable modem and DSL services, as well as some services that may not quite meet the definition. There is disagreement over the term. Until March 2008, the FCC defined a service as *broadband* if it was at least 200 Kb/s in one direction; many other organizations set the bar higher. Under the new FCC definition, broadband begins at 768 Kb/s.

Table 1 shows the availability as of June 2007 of services to U.S. homes and businesses with rates above 200 Kb/s. Clearly, the dominant broadband services in Table 1 are cable modem service and DSL. Mobile wireless (cellular) is also common, although some would not call this service broadband. There are also important alternatives beyond these three. The often contentious debate over which of these services can rightfully be called broadband has obscured a more complex reality; these are diverse services with different advantages, such as higher downstream data rate, or higher upstream data rate, or better mobility. Thus, while expanding the availability of all services is beneficial to consumers, we will later delve deeper into exploring the relative importance of these services for bringing broadband Internet to unserved rural communities.

Figure 1 shows the overall percentage of Americans using the Internet at any speed, a figure that has grown by almost a factor of five from 1995 to 2007, and is currently holding steady at more than 70 percent (Figure 1). The majority of Internet users want access from home. Increasingly, they also want broadband. Figure 2 shows that the number of households subscribing to broadband (as defined by survey respondents) is growing rapidly in the United States, to some degree because new customers are choosing broadband but in large part because current dial-up customers are switching to broadband (Horrigan and Smith 2007).

TABLE 1

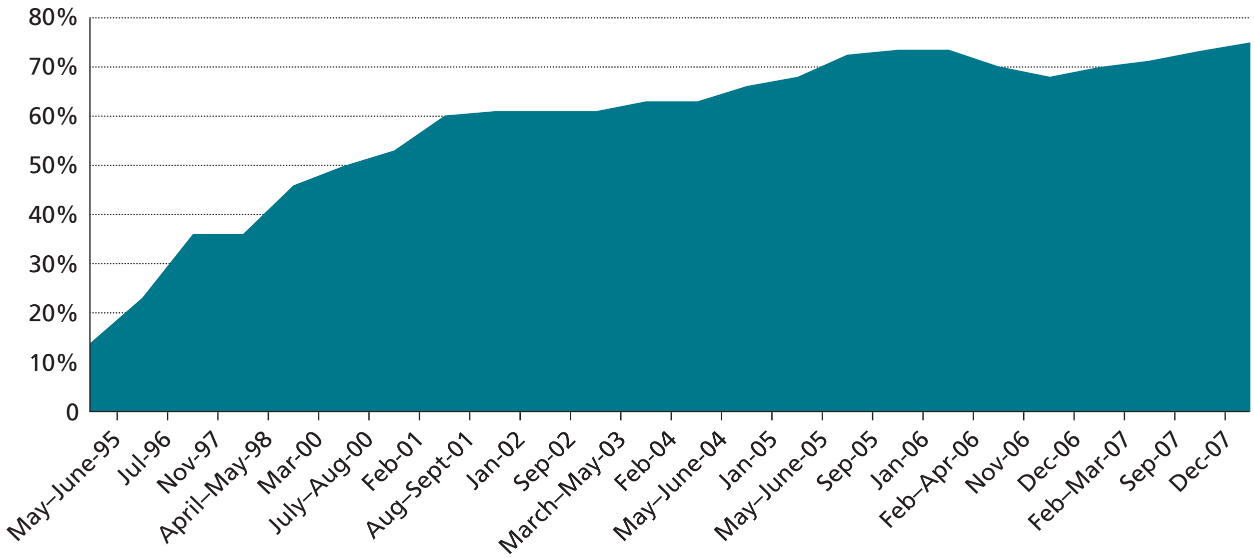
Number of Lines with Downstream Capacity Greater than 200 kb/s, June 2007

Technology	Number of lines (in millions)
Asymmetric DSL	27.516
Symmetric DSL & traditional wireline	1.029
Cable modem	34.409
Fiber	1.403
Satellite	0.669
Fixed wireless	0.586
Mobile wireless	35.305
Power line and other	0.005

Source: FCC 2008d.

FIGURE 1

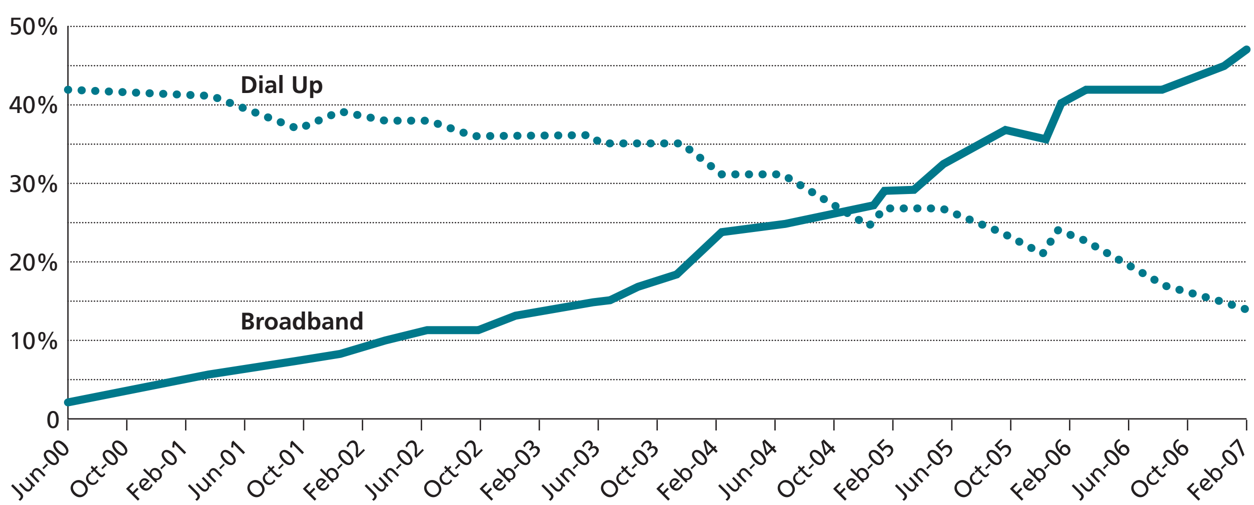
Percentage of Adults in the United States Using the Internet, 1995–2007



Source: Pew Internet & American Life Project Surveys. March 2000-December 2007.

FIGURE 2

Percentage of U.S. Adults with Broadband and Dial-up Access, 2000–2007

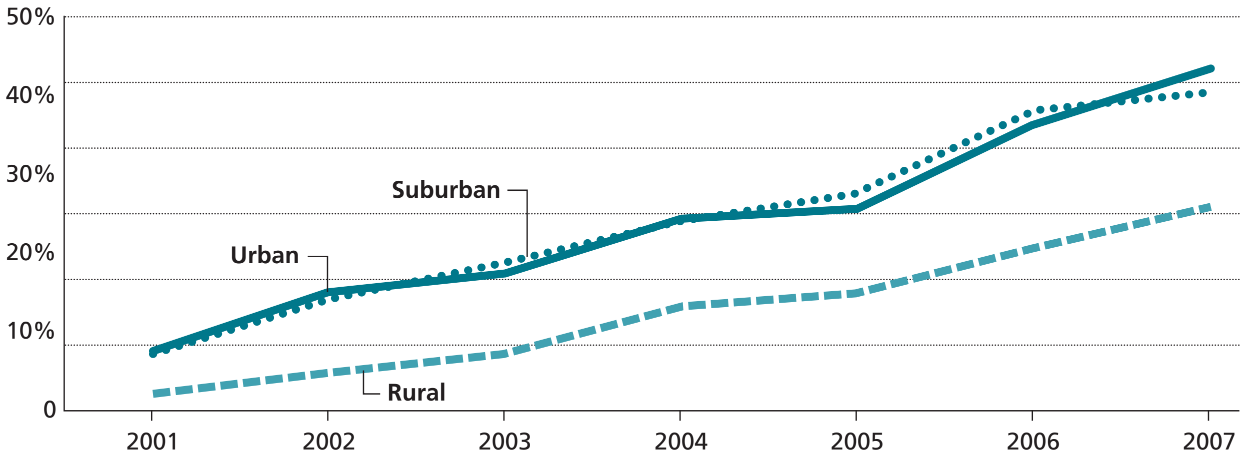


Source: Horrigan and Smith 2007.

However, not all parts of the country are sharing equally in this growth in broadband penetration. Figure 3 shows that rural communities have lagged far behind their urban and suburban counterparts (Horrigan and Smith 2007). Is this because rural communities have much less interest in Internet? Not according to the Census data shown in Figure 4, which shows that the fraction of rural households subscribing to Internet service is just below the national average, but rural users rely far more on dial-up and far less on broadband (National Telecommunications and Information Administration [NTIA] 2008). This is because many of them are unable to switch to a faster connection due to the unavailability of broadband where they live.

FIGURE 3

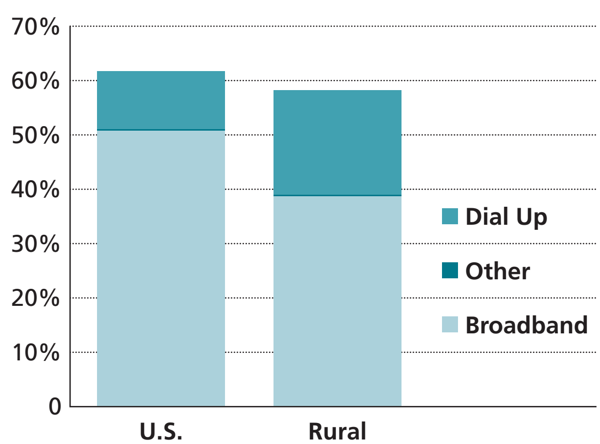
Percentage of U.S. Adults with Broadband in Urban, Suburban, and Rural Areas, 2001–2007



Source: Horrigan and Smith 2007.

FIGURE 4

Percentage of Households with Internet in Rural United States and Entire United States, October 2007



Source: NTIA 2008.

Moreover, the rural demand for broadband can be seen from the level of utilization for those who do subscribe. Rural households transfer more information on average than their urban counterparts. This may be because rural users turn to the Internet for products and services that they cannot get locally, whereas urban users have more options.

This disparity of access exists because the cost per household of providing broadband is far greater in rural areas. The fact that rural households make greater use of broadband is a contributing factor, but the more important differences are rooted in the nature of broadband technology. The majority of broadband subscribers get their service from wired infrastructures that were not initially intended for Internet and were subsequently upgraded: DSL over telephone networks, cable modem service over cable TV networks, and broadband over powerline (BPL). There is a significant cost to upgrading these networks to support broadband, and the cost per potential subscriber increases with the distance from each customer to the nearest aggregation point, which is much greater in sparsely populated areas. Telephone infrastructure is almost ubiquitous in the United States, but problematic for rural broadband because telephone companies have built fewer central offices in these areas. The farther a home is from a central office, the lower the capacity that can be achieved using DSL. Beyond roughly three miles from the central office, DSL is not an option. This may explain why incumbent local exchange carriers (LECs) across the United States have made broadband available to just 82 percent of their (non-Internet) subscribers, compared with 96 percent for cable companies (FCC 2008d). However, cable modem service is also a problematic option: perhaps half of the currently unserved rural communities have no cable infrastructure to upgrade. (As will be discussed later in this section, better data are needed to know this fraction more precisely.)

Two other wireline options are currently even less appropriate for widespread use in rural areas. Carriers have begun rolling out fiber networks in the larger cities, which offer a ten-fold or greater increase in capacity beyond cable and DSL service. Verizon FiOS service, for example, is now available to 10 million homes (Verizon 2008). However, these next-generation systems will not come to rural areas in the near future. A final option is BPL. There are a number of trials under way, but the technology is not a cost-effective competitor at this time (Tongia 2004).

If one were to build an entirely new network in a rural area rather than add new capabilities to an existing infrastructure, wireless technology would clearly be the way to go. Today, the closest wireless competitors to current DSL and cable services typically provide data rates of 1 to 10 Mb/s to stationary wireless devices. Examples include citywide networks based on Wi-Fi technology (http://www.muniwireless.com), the newer WiMax standard (http://www.wimaxforum.org), and various proprietary solutions. Fixed wireless can be an attractive option for unserved communities, because the cost per subscriber of building new infrastructure is far less than a wired system. There is no need to dig ditches and lay long cables out to remote households. The cost of equipment that sits at the customer's premises is roughly the same for rural and urban areas. The cost per household of the towers may still be greater in sparsely populated areas because there are fewer customers per tower, but this is still much cheaper than deploying new wireline connections. Thus, bringing broadband to an unserved community often means choosing between building an entirely new system using fixed wireless technology, and upgrading an existing telephone or cable system.

In addition, cellular providers are introducing data services using a different set of wireless technologies. Subscribership has been increasing at an astounding rate, from 3 million in December 2005 to 35 million in June 2007 (FCC 2008d). These services typically have much lower data rates (e.g., hundreds of kb/s) than fixed wireless, DSL, or cable, and much higher monthly prices, but they offer substantially better mobility. Thus, they typically meet somewhat different needs, and often serve the same customer base as cable or DSL. We can expect continued growth in these mobile services, especially after the digital television (DTV) transition when more spectrum becomes available to cellular carriers (notably Verizon and AT&T). In the process, some services may become available in communities that do not have broadband today, although it is more likely that growth will be focused in larger cities.

A final noteworthy wireless technology for rural areas is satellite service, which can boast almost seven hundred thousand subscribers (FCC 2008d). Satellites can serve any household that can point a dish to the southern sky, so it is perfect for reaching the most remote households. Satellite service is sufficient for e-mail, and limited web browsing. Unlike the broadband services described above, though, satellite is inadequate for many other applications. It takes about a quarter of a second to bounce information off a geosynchronous satellite, which makes satellite service inherently deficient for interactive service, such as voice over IP (VOIP), or videoconferencing. Because of the cost, satellite capacity is also typically severely limited in the upstream, which can be a problem for those who produce and share as well as consume content. Thus, while satellite service is important, it should not be seen as the equivalent of today's cable, DSL, or fixed wireless broadband services.

The economic costs and technological limitations blocking the expansion of broadband leave many rural communities underserved. Unfortunately, although the data show how many Americans subscribe to broadband, no one knows how many Americans actually lack access to broadband, which is a significant impediment to expanding access. There have long been concerns about the inadequacies of the data we gather (Flamm et al. 2007), and misleading statistics are disturbingly easy to find. For example, widely cited government reports (FCC 2008d; NTIA 2008) indicate that as of December 2006, in 99.6 percent of the thirty thousand five-digit zip codes in the United States containing households, broadband (by the old definition) was available, which means the service was available to at least one subscriber. Indeed, four or more broadband providers each served at least one customer in 82.6 percent of these zip codes, and ten or more served 22 percent of these zip codes. Although this is often cited as proof that broadband is nearly ubiquitous and that the broadband market is intensely competitive, it actually proves very little. Rural zip codes typically cover large areas. Some zip codes may have a dozen broadband providers, but very few households have more than two or perhaps three from which to choose, and, as shown below, many have none. (Similarly, there is probably at least one multimillionaire in every zip code, but it would be absurd to conclude from this that most Americans are millionaires.) Moreover, even these figures are based on reports from service providers to the FCC that are not externally verified, and some question their accuracy.

If we do not count satellite service due to its limited data rate, it appears that cable modem service is available to more Americans than is any other form of broadband. If we assume that cable industry estimates (National Cable & Telecommunications Association n.d.) are accurate, broadband cable modem service was available to 117.7 million homes as of December 2007, including homes that were vacant at the time.[1] Combined with census estimates, this means that 10.4 million homes, i.e., 8.1 percent of all U.S. homes, were not able to subscribe to broadband cable.[2] It is impossible to tell from public data how many of these 10.4 million homes could access other forms of broadband. DSL is the most obvious alternative, but DSL service was available to only 82 percent of homes served by incumbent local-exchange carriers (FCC 2008d). Given that both DSL and cable broadband services are more concentrated in urban areas, most of those who cannot get cable modem service also cannot get DSL. Thus, we can only roughly estimate the number of unserved households, and it should be

1. Some reports simply add the number of homes passed by each cable operator and get a slightly higher number. Due to what the cable industry calls "overbuilds," several million households are passed by more than one cable operator. Unlike some other reports, the figure cited in this paper counts such households only once.
2. According to the U.S. Census, there were 126.32 million homes in 2006 (U.S. Census Bureau n.d.(1)). From 2003 to 2006, this number increased at a rate of 1.4 percent per year (U.S. Census Bureau n.d.(2)). Thus, we estimate 128.1 million homes in 2007.

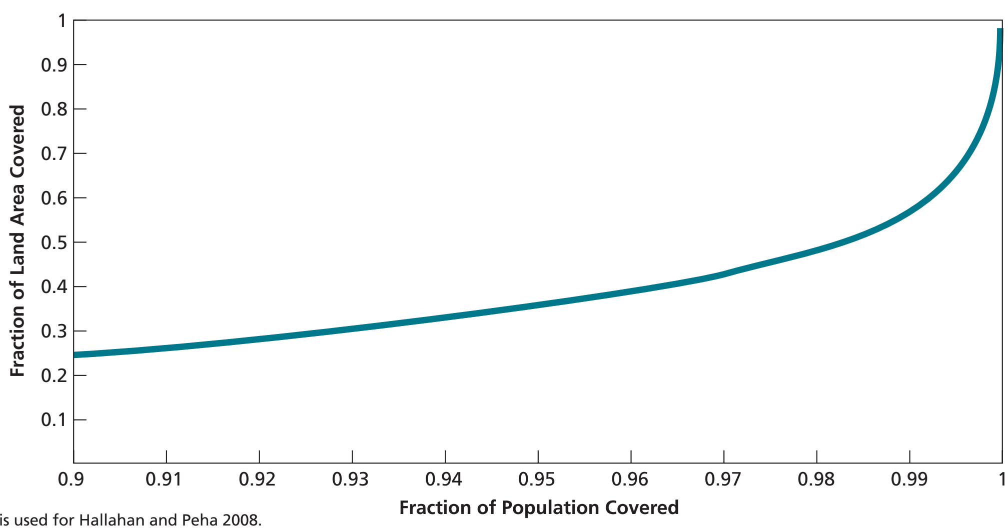
in the neighborhood of 9 or 10 million. If most those households are rural, this is roughly a third of rural households.[3] This, combined with Figures 3 and 4, would imply that there is very little difference in the percentage of rural and urban households subscribing to broadband services where those services are available. Thus, contrary to what some believe, lack of available infrastructure is the primary cause for the rural-urban digital divide as exemplified in Figure 3.[4]

To determine the precise number of unserved homes—and more importantly to map out their locations and estimate the cost of serving them—more detailed information is needed. It is no surprise that in other efforts to extend broadband to unserved communities such as ConnectKentucky (http://www.connectkentucky.org), the first step was to better inventory existing infrastructure. Recently announced improvements in data collection at the FCC (2008b) may help, although it is too early to tell. Otherwise, this needs to be a priority for policymakers.

When such data is available, we may also assess whether there are significant number of households for which the cost of a non-satellite solution is unreasonable. As described above, cost increases as population density falls. (Other factors such as terrain and climate also play a role.) Figure 5 shows our analysis of the percentage of U.S. area that must be covered to serve a given percentage of the population. In the absence of actual data, we make the simplifying assumption that for some threshold *T*, all residents of counties with population density above *T* have broadband access, and no residents of counties with population density below *T* have access. The additional area one must serve when passing 91 percent of the population instead of 90 percent of the population is comparable to that additional area when passing 95 percent instead of 94 percent. However, going from 99 percent to 100 percent requires a far greater increase in area, implying that this last 1 percent may not be reached easily by terrestrial services. This county-level analysis may exaggerate the relative costs of serving the last unserved communities, but it is difficult to know until we have better data.

FIGURE 5

Minimum Percentage of U.S. Area Needed to Serve Counties with Given Percentage of U.S. Population



Source: Analysis used for Hallahan and Peha 2008.

3. In the 2000 U.S. Census, 22.38 percent of households were rural. Assuming the same percentage in 2007 would yield 28.7 million rural households. In reality, the percentage of rural households probably fell from 2000 to 2007, so the number of rural households is probably less than 28.7 million.
4. Some studies have mistaken the large differences in rural and urban broadband penetration in the United States to be indicative of a similar difference in demand. Explicit consideration of infrastructure availability can lead to qualitatively different conclusions (Tengtrakul and Peha 2008).

3. Impact on Communities without Broadband

Internet access brings a wide range of benefits and advantages for all communities. This is especially true for rural and remote areas, because the Internet brings access to resources that are even less likely to be available in these communities. For example, individual households gain an educational tool of immense value. Today, there are adults working toward college degrees offered by distant universities, high school students writing term papers on material that they could never find in the local library, and parents using the Internet to monitor what their kids are doing in school. The Internet has also become a leading source of important medical and health information for patients and their families. Moreover, broadband Internet connections may become, in time, an essential component of home health care, allowing anything from remote real-time monitoring of a patient's condition to videoconference consultations with experts that are a thousand miles away. The Internet also provides access to the world's largest marketplace, filled with countless products that could never be found in the stores of a rural community. As a final example, many Americans routinely work from home, thanks to broadband Internet connections. Indeed, for some professions, life without easy access to broadband Internet is now hard to imagine.

While benefits such as these accrue to residents of households with Internet access, these residents are not the only beneficiaries. Expanding Internet access in a community can bring significant benefits to the entire community. If broadband is not available, it can be harder for some kinds of businesses to attract to the region the skilled workers they need, or to stay sufficiently connected to employees who are currently off site. Broadband is also a prerequisite for the creation of many home-based businesses. If local businesses find themselves at a competitive disadvantage with those in other regions, the entire community may risk the loss of both jobs and tax revenues.

It is notoriously difficult to quantify the impact of information technology (IT) on economic indicators, as demonstrated by the "productivity paradox" that has plagued economists (Triplett 1998).[5] Nevertheless, early research is consistent with the premise that broadband Internet can bring jobs and new businesses to a community. Lehr, Osorio, Gillett, and Sirbu (2005) analyzed time-series data from regions throughout the United States from 1998 to 2002 and found significant differences between those that had broadband by 1999 and those that did not. Their results are based on the relative performance of communities that are comparable with respect to relevant variables other than broadband availability, such as income, population density, and the percentage of the population with a college education. To the extent that they could correct for such factors, they could show how broadband availability affects economic development, as opposed to economic development affecting broadband availability. They found that the availability of broadband added more than 1 percent in job growth rate; not surprisingly, a disproportionate amount of that growth was in IT–intensive sectors. Broadband also increased the number of new businesses established by almost 0.5 percent in the typical region. These analytic results are consistent with the conclusions of a study on Appalachia, where it was observed that lack of broadband had a "profound effect on the growth and diversification of locally based manufacturing, service, and trade sectors," as well as being "a particular problem for the health care sector" (Oden and Strover 2002, 104).

Bringing broadband to an area also makes houses throughout that area more desirable, and can therefore increase property values, even for those who

5. As economist Robert Solow once quipped, "You can see the computer age everywhere but in the productivity statistics."

do not use broadband. This is consistent with the above study (Lehr et al. 2005), which found that areas with broadband had 7 percent higher residential rental rates compared with areas that lacked broadband but were otherwise comparable.

Another way entire communities can benefit from broadband is through improved government services. Local governments can use broadband for many things. For example, public safety agencies can use broadband to send blueprints of burning buildings to firefighters, video of accident victims to medical specialists, and pictures of abducted children to police in the field (Safecom Program 2006). As we have seen in our recent study of the Pittsburgh Bureau of Police, simply allowing police to file reports via wireless broadband connections from their cars allows them to spend significantly more time in the field, where they can respond to and deter crime. Other cities have used broadband infrastructure to serve public schools, to reduce costs and increase revenues from parking meters, to manage municipal vehicle fleets (e.g., snow plows or school buses), to improve emergency medical services, to support sensors that detect problems in water and sewerage systems, and more. (However, it is important to note that municipalities vary greatly; some can use broadband infrastructure to significantly improve service and cut costs, while some municipal governments have little need for broadband [Peha 2008b]).

The fact that the benefits of broadband can accrue to all members of a community, while only those who subscribe to broadband pay for the service, creates what economists call a positive externality. This is a classic cause of market failure. In the absence of countervailing public policies, societies will underinvest in infrastructure of this kind, because the market does not account for the benefit to those in the community who do not use the infrastructure. This is one reason that many municipalities have considered investing their own funds in the deployment of a wireless metropolitan-area network (WiMAN), but there are many more communities where local government has neither the resources nor the incentive to pay the entire cost itself, even if it would be willing to pay a part.

Moreover, citizens in the previously unserved region are not the only ones to benefit when broadband infrastructure is expanded. As more people join any communications network, those who already belong to the network gain because they can communicate with more people. This phenomenon is known as "network effects." For example, network effects are the basis of the oft-cited Metcalfe's Law and its cousins (Briscoe, Odlyzko, and Tilly 2006; Tongia and Wilson 2007). Metcalfe's Law states that the benefit of a network with n users is proportional to n^2, because that is roughly how many pairs of people can communicate over the network. For example, as new users join the network, e-commerce merchants can attract more customers. Online universities can attract more students. Social networks can attract more members. Blogs can gain more readers of content, and more generators of contents. Users of e-mail, VOIP, and videoconferencing can communicate with more friends and business associates. Despite these advantages, none of these beneficiaries pays to add these new users. Thus, making broadband available in unserved areas benefits all of those Internet users who might want to communicate with members of that community. This creates another positive externality, and another reason why society may underinvest in expansion of the infrastructure. (For discussion of other externality examples, see Atkinson 2007.)

While some of these exchanges can occur over dial-up, in practice many exchanges depend on broadband. Surveys tell us that users with broadband access make far greater use of many Internet capabilities than those with dial-up access. For example, broadband users are far more likely to use the Internet to get news, buy products, bank, or create a blog (Fox 2005).

The reasons to prefer broadband are obvious for most applications that are rapidly gaining in popularity today. Indeed, these applications are gaining in popularity specifically because so many of the nation's Internet users now use broadband. Many applications such as VOIP, video conferencing, and video streaming require higher data rates or lower latencies than dial-up can provide. Peer-to-peer (P2P) makes use of the always-on capability of typical broadband, as well as its greater capacity. The very basis of Web 2.0 is that users can both consume and produce content; often that content includes images and video. Transfer of such content is painfully slow over dial-up.

What is less obvious but perhaps even more important is that the applications that once worked well over dial-up are now becoming problematic for dial-up users. As Figure 2 showed, the growth of broadband nationwide has coincided with and almost certainly caused the rapid decline of dial-up. As a result, many websites are now designed around the assumption that viewers will have broadband. Consequently, web page sizes have grown dramatically (Tongia and Wilson 2007), as they fill with data-intensive graphics and images where one once found simple text. Many pages actually require the retrieval of content from multiple sites. By design, none of this is noticeable to broadband users, but it has vastly decreased the pace at which dial-up users can browse content on the World Wide Web (Tongia and Wilson 2007). Even e-mail has become less useful. Simple text-based e-mail has mostly been replaced by larger HTML-based messages; worse, they often come with large attachments. Broadband users may not think twice about sending e-mail messages of 1 MB or more, but dial-up users know they often spend minutes retrieving such a message. Even passive activities that designers tend to assume occur unnoticed in the background are now a problem for dial-up users. For example, routine updates to operating systems, antimalware software, and numerous applications are often downloaded automatically in a manner that barely affects users of broadband, but can slow the activities of dial-up users to a crawl.

This impact on dial-up users demonstrates how making a service like broadband available to most but not all of society can actually harm those who are excluded (Tongia and Wilson 2007). If broadband is available to 10 percent of Internet users, then the minority of broadband users get an added convenience, but most of the Internet applications and content will still be designed for dial-up users. If broadband is available to 90 percent of Internet users, then much of the Internet will no longer be designed for or particularly useful to dial-up users, and those users see the Internet as less and less valuable. This is another implication of network effects; as some dial-up users switch to broadband and the number of members in the "dial-up network" decreases, so does the benefit for each dial-up user. Those who do not use the Internet also share these adverse effects. For example, as broadband use grows, more consumers get product information from the Internet, so companies have less reason to establish phone lines for customer support. As more travelers purchase airline tickets and check in online, airlines place extra charges and delays on those who cannot. As more citizens get tax forms and other government information over the Internet, government agencies have less reason to make paper versions easily available. In short, the more it is assumed that many households and at least some households in all communities have access to broadband, the more those communities that still do not have broadband will lose capabilities and conveniences that they once had. This may further motivate policymakers who are concerned about rural citizens to help make broadband available in unserved communities.

4. A Proposed Suite of Policy Reforms

To encourage the expansion of broadband into currently unserved communities, policymakers can adopt a complementary suite of interrelated policies that will reduce the cost of deploying infrastructure, reduce the uncertainty over future revenues, and, to the extent funding is available, provide highly targeted subsidies that leverage existing market forces.

First, policymakers should make more spectrum available, a significant portion of which is regulated in a way that is conducive to the deployment of new fixed wireless broadband systems in rural areas. Second, policymakers should allow the new wireless service providers that emerge in these bands, along with established telephone, cable, cellular, power companies, and other interested organizations to bid in a competitive auction. The winner of this auction would accept obligations to make broadband services available, in return for a one-time subsidy, the size of which is determined in the auction. These obligations to provide broadband services would be highly flexible, and each provider would be free to trade obligations (or components thereof) in an open market so as to adjust both what the provider must accomplish and when. Moreover, auction winners would also agree to somewhat limit the extent to which they can discriminate with respect to content, applications, and devices, in those areas where they have successfully bid for subsidies. Third, local governments should be brought in to play a greater role in universal service policy.

This combination of policies addresses several problems with current and proposed approaches. First, because fixed wireless is the most cost-effective technology for an entirely new network, the most important way to reduce the cost of a greenfield deployment is to reform spectrum management policies, as described further in §4.1. In addition to encouraging new entrants to deploy a greenfield infrastructure based on wireless technology, the heightened threat of a viable new entrant can motivate an existing telephone or cable company to upgrade sooner than it otherwise would. After all, in a region where demand does not justify multiple providers, the company that moves first can expect to be the sole broadband provider for many potentially profitable years to come.

The reverse auction method introduced below is a common way to find the organization that will provide a given product or service at the lowest price. It is used in many contexts. Some companies (DeJordy, Mowery, and Rubin 2007; Heimann, Phillips, and Mancini 2007) have recently suggested its use to establish a broadband provider in unserved areas, and the idea of a limited pilot program using this approach has become one of many issues drawing comments in an ongoing FCC proceeding (FCC 2008f). The idea has many important merits, but establishing a reverse auction without making complementary policy changes is likely to lead to problems. First, successful auctions require competition among bidders. If there is only one serious bidder, then that bidder will win the auction and receive an excessively high subsidy. For example, reverse auctions in Australia (International Telecommunication Union 2006) and India (Noll and Wallsten 2005) were won by the incumbent phone company at the maximum possible subsidy because there were no rival bidders. Even if there are multiple organizations interested in bidding, there is a problem if the disparity in what it would cost each to provide the service is too great. For example, if an incumbent phone company can meet the stated obligations at significantly lower cost than any other current or potential provider, then there will be little or no competitive bidding. Thus, spectrum policy reform that facilitates new greenfield entrants is an important component to any universal service policy that includes an auction.

Another serious problem with typical auctions of obligations to provide broadband service is that one must allow all bidders to compete evenly so that the least costly approach wins, but it is exceedingly difficult to establish these obligations in a way that does not favor a specific technology or a specific provider. For example, over what area must the auction winner provide broadband service? It is a highly contentious issue when an auction includes traditional build-out obligations (FCC 2008f). An incumbent LEC would want this to correspond exactly with its current service area or "study area," while the area preferred by a start-up that is considering wireless technology would be based on terrain and the most promising locations to place transmitters. According to analysis from the Cellular Telecommunications Industry Association, "geographic areas which correspond to an incumbent LEC's study area (or contiguous portions thereof) might discourage participation in the auction by competitive carriers" (FCC 2008f, 9) (where the "competitive carriers" here are generally wireless carriers). Thus, simply by establishing the geographic region to be served, designers of a reverse auction may strongly favor one technology over another, and therefore one provider over another. This may prevent adoption of the most cost-effective technology. Even if the auction rules happen to favor the most cost-effective approach, these restrictions may undermine the competitiveness of the bidding process, thereby vastly increasing the subsidies required.

If it is not possible for a regulator to consistently define obligations that are cost effective and technology neutral, the next best thing is to give broadband providers the ability to adjust obligations to fit their existing infrastructure (if any) and their technology choices. Moreover, providers should be able to adjust their plans in response to changing technology and market conditions. None of this is possible with a typical reverse auction. In effect, when the obligations associated with an auction are set, the government must play the role of long-term central planner, and central planning is notoriously difficult in this fast-moving sector. Moreover, unlike those lucky central planners of the former Soviet Union, even the government cannot easily change its own plan after an auction of this kind is over. We propose to address these problems by defining a new kind of obligations, obligations that are flexible and tradable (Peha 1999), as described in §4.2. Broadband providers will trade obligations in an open market, thereby assembling the set of obligations that minimize cost and maximize financial viability.

Even where an auction mechanism successfully yields a broadband provider through a relatively small one-time subsidy, there is a danger for consumers: that provider is likely to be a monopoly for some time. As described in §4.4, policymakers should take advantage of the fact that these monopolies were created in part with government subsidies by adding some lightweight constraints to the obligations of auction-winners that will prevent them from taking excessive advantage of their monopoly power, without seriously undermining revenues. To do this, this issue must be addressed when defining the tradable obligations, rather than after the auctions are completed.

While there are many things the federal government can do to advance universal access, local governments also have important roles to play; this is sometimes ignored. Indeed, there are states where local governments are unfortunately prohibited from some types of action. Before an auction takes place, local governments can guarantee future revenues as a potential customer, and can make important resources available to future broadband providers, thereby encouraging organizations to bid. In return, local government agencies can gain added assurance that useful services will be available. This aspect is described further in §4.3.

4.1 Making Spectrum Available for Broadband

Spectrum for a new broadband system is not always easy to come by. In the long run, this shortage of available spectrum results more from outdated spectrum management policies than from the laws of physics, or the capabilities of modern technology (FCC 2002; Peha 2007a). Indeed, if one actually measures spectrum utilization in a busy city, one finds that the majority of prime spectrum sits idle at any given time and location (Spectrum Efficiency Working Group 2002); the percentages are even higher in typical rural areas.

One reason for this scarcity is spectrum management policies rooted in the technology of the early days of the FCC—the 1920s and 1930s—that allow little spectrum sharing. In much of the spectrum, licenses are granted that give the license holders exclusive rights to blocks of spectrum. This is an effective way to prevent interference, but it leads inevitably to inefficiency, because spectrum will sit idle at times when and locations where spectrum is not needed by the license holder. New technology (Peha forthcoming) combined with new policies (Peha 2007a) can make far greater use of spectrum, thereby making spectrum available for new products and services. One of these new services might be the "last mile" broadband connection from homes or businesses to an Internet service provider (ISP).

Thus, the first priority for policymakers should be to make more spectrum available to current and future service providers. This responsibility will fall primarily to the FCC and the NTIA. Policymakers at NTIA and the FCC should seek spectrum reforms that either allow rural broadband providers to share spectrum with incumbent users, or that help incumbent users to give up their spectrum entirely. This section includes some ideas that deserve consideration; serious efforts at spectrum reform could produce many more.

Simply making spectrum available is not enough. Contrary to popular myth, all spectrum does and must come with some constraints. Even if the regulator does not restrict usage to a specific application such as TV or cellular telephony, those constraints inevitably make the spectrum more useful for some applications and less useful for others. Thus, it is important that some available spectrum have constraints that are suitable for rural broadband. There is no consensus on what policies are best for broadband Internet, in part because one must make tradeoffs. For example, some arrangements are better for an Internet service that emphasizes dependable quality of service, and other arrangements are better for a service that emphasizes cost minimization. Ideally, different bands should be available with different policies so that different firms can provide different kinds of Internet services and consumers can choose.

Some useful spectrum has become available in recent years, but it probably will not fully solve the problem. In 2005, the FCC made spectrum available at 3650–3700 MHz that may prove suitable for rural broadband systems (FCC 2005b), potentially with WiMAX technology (http://www.wimaxforum.org), although its relatively high frequency will limit the area that can be covered by each transmitter, thereby increasing the cost of build-out. The DTV transition of 2009 will also bring tremendous opportunities, as TV broadcasters vacate far more valuable spectrum. The physical properties of this spectrum make it well suited to cover large areas at low cost, so it is attractive for rural broadband. However, much of that spectrum will go to cellular carriers. As discussed in §2, they are likely to provide an expensive but mobile version of data service. This may help a few unserved communities, but there is likely to be more effort in the coming years to bring advanced services to regions that are packed with people willing to pay the relatively high monthly prices, rather than those remaining regions that lack fixed broadband today. Policymakers should look elsewhere for opportunities to reach unserved communities.

One way to make spectrum available is to allow the use of the "white spaces" of the television band. A benefit of the DTV transition is that DTV will be immune to interference than is today's analog TV, which facilitates spectrum sharing. For this reason (and others), it should be possible to deploy wireless systems in the TV white spaces, i.e., within a band of spectrum that is used for a given TV channel, but in a location where that TV channel is not available. These white spaces are there for good reason: as buffer zones to protect broadcasters in different cities from interfering with each other's signals. However, advances in technology make it possible to use parts of the white space while affecting a relatively small fraction of TV viewers. The FCC is currently considering use of the white space after the DTV transition in 2009, although many specific issues remain undecided (FCC 2006). There have been prominent efforts by high-tech companies to create relatively low-power devices that operate in this band (FCC 2007a). Such devices would use cognitive radio to find a channel in which no nearby TV broadcaster is active. These devices could even be mobile or portable, because they will dynamically adjust when they find themselves to be too close to a TV transmitter. Low-power devices could serve many useful purposes. If the objective were to connect households to a rural ISP, however, it would be far more important to operate at high power and less important to support mobility. Thus, the FCC would establish very different regulatory constraints for use of the white space. If there were companies with a serious interest in using this spectrum to bring broadband to unserved areas, it would be in the public interest to allow these high-power devices into at least some of the TV channels.

Naturally, the FCC should make spectrum available for those applications with significant demand. So far, there are companies who have expressed strong interest in developing low-power unlicensed devices that operate in the TV white space, but not the same level of interest from organizations pledging to deploy high-power transmitters for fixed Internet service in the white space. Perhaps that will change in the future, especially if the FCC explicitly solicits input on this in a future proceeding, and if there is the possibility of subsidies and tradable obligations for rural providers, as described in this paper. Such a policy change in this band might substantially improve the business case for serving rural areas with broadband service.

A second option in addition to spectrum sharing is to make a complete underutilized band available for broadband use. There are several candidate bands already under consideration. One is 2155-2175 MHz. The entrepreneurial M2Z Networks proposed using this band to construct a nationwide broadband network that offers fixed wireless service, after moving the incumbent license holders to another band (M2Z Networks 2006). Other firms have responded with similar proposals. At present, the FCC has not made the spectrum available. A broadband provider in this or another nationwide band may or may not focus initially on currently unserved areas; it must weigh the benefits of being the sole provider against the benefits of competing in a much larger market. However, the creation of a system of tradable obligations may induce a nationwide provider of this kind to bid on unserved communities. Indeed, it is even possible to package obligations with the spectrum when it is assigned. If this is done, the tradable approach is far more efficient than traditional build-out requirements, because the new license holder can decide for each unserved community whether it is cheaper to expand wireless infrastructure in that area or to help fund an existing telephone or cable company to make the necessary upgrades for broadband. Either option could meet the obligation.

A second opportunity to provide spectrum nationwide for broadband is through the current efforts to provide communications systems for public safety agencies, such as fire departments, police departments, emergency medical services, the National Guard, and various federal agencies (Peha 2007b). The communications systems used for public safety in the United States are inadequate on many levels. They do not easily support communications across bureaucratic boundaries, they are unnecessarily prone to massive outages when single components fail, they generally lack broadband capability and other advanced services, and they consume billions of taxpayer dollars unnecessarily. In short, the many inadequacies of the U.S. system cost money and lives (Peha 2005, 2007b). One proposed solution to this problem is to create what the FCC refers to as a "public-private partnership" whereby a commercial company would build a single nationwide broadband network that serves public safety agencies as well as paying customers from the general public (FCC 2007b). Unfortunately, current proposals would only provide terrestrial wireless coverage to 73.5 percent of the continental United States and 63 percent of the United States (Public Safety Spectrum Trust 2008), which means the network would be inadequate for both rural public safety agencies and communities that are not served by commercial broadband. In contrast, today's public safety wireless systems cover 96.0 percent of the continental United States, and 83.2 percent of the United States (Hallahan and Peha 2008; Peha 2008a). When this problem is rectified to meet public safety needs, so that the new nationwide system operates everywhere that local systems operate today, then the network will reach many unserved communities, and it will probably have excess capacity in those communities. Thus, it would cost little to provide commercial broadband services in these regions. This may lead to significant infrastructure expansion into unserved areas even without tradable obligations, and perhaps more when the public-private partnership can bid for tradable obligations.

Another way to access additional spectrum bands that could be used exclusively or on a shared basis for broadband is through freeing up spectrum currently used by the federal government. Although the greater pressure to make spectrum available typically falls to the FCC, the agency that manages spectrum for nongovernmental users, by far the largest user of spectrum in the United States is the federal government. Federal spectrum is managed by NTIA, whose processes and procedures do not encourage efficiency (Peha 1998). A recent directive urges federal agencies to consider the value of their spectrum, as determined by comparison to prices obtained for similar bands in commercial markets, when purchasing new wireless systems (OMB 2008); this is a step forward. Nevertheless, federal agencies that reduce their use of valuable spectrum must often accept the burden of one-time transition costs, and there is no reward for agencies that go out of their way to do so when the process is over. Some funding exists that could help to support these transitions (OMB), and additional mechanisms could certainly be established through which those who gain access to spectrum cover the costs of those who relinquish the spectrum, as occurred with the personal communications services band in the 1990s (Cramton, Kwerel, and Williams 1998). However, government agencies lack incentive to seek out such arrangements. Those that want the spectrum, including future broadband providers, lack the means of identifying opportunities.

Many have attempted to free federal spectrum, and few have succeeded. An important first step is to move the management of federal spectrum out of the closet. The next president should demand a detailed inventory of federal spectrum and how this essential resource is used. Except for those bands that must be protected for reasons of national security, the results of this inventory should be made public. This would allow existing companies, entrepreneurs, and researchers to seek out opportunities to use the spectrum more efficiently. Those who find opportunities can make their case to the NTIA, to the current license holder, and to Congress.

4.2. Reverse Auction and Tradable Broadband Obligations

In a reverse auction, bidding begins at the maximum amount that the holder of the auction is willing to pay. Each bidder indicates the amount of subsidy it would require to meet the stated obligations, and the bidder that is willing to accept the smallest payment wins.

This general approach has many advantages. It is easy to limit total payment to what one is willing to pay simply by setting the starting place for the bidding. Thus, if the cost per subscriber for a given rural community exceeds what policymakers set as the appropriate limit, then there will simply be no bidders and no subsidies to serve that area. The winner of a reverse auction will generally be the provider that can meet the stated obligations at the lowest cost. Moreover, if (and only if) there are multiple providers that can meet obligations at similar costs, competition among providers will drive bids close to the minimum, which tends to reduce the subsidy required to build out broadband infrastructure to the extent described before the auction. Indeed, in the special case where two or more bidders estimate that it is already profitable to serve a given area, they will bid until the subsidy required is zero. The winner will then be obligated to deploy infrastructure without subsidy. (International experience shows that this does happen sometimes.) Thus, there is no danger under these circumstances in offering subsidies to serve communities that would have been served anyway.

An enormous challenge in devising a reverse auction for broadband providers is defining obligations in a manner that allows all bidders to compete evenly despite differences in their technologies, and that gives auction winners the ability to minimize costs and maximize revenues while still meeting the intended objectives. Under a system of tradable obligations first proposed in Peha (1999), auction winners are assigned a collection of obligations, which consist of both milestones to achieve and deadlines by which to achieve them. However, these obligations are entirely tradable.

The idea is an extension of pollution permits—one of the great innovations in pollution reduction. A permit allows a company to emit a given amount of pollutants into the atmosphere. By controlling the number of permits in circulation, the government can limit the total annual pollution rate. Permits can be sold and traded. A factory that can reduce its pollution levels inexpensively will sell its permits to a factory that cannot. Thus, by giving individual polluters greater flexibility, tradable permits allow an industry as a whole to meet specific objectives for pollution reduction at the minimum cost.

While there are useful lessons to be learned from the permits used to reduce air pollution and the emission of greenhouse gases, there are also important differences. Two aspects of tradable universal service obligations make matters more complicated than the established systems. First, with universal service firms are trading obligations rather than permits. Second, because the objective of the proposed policy is to motivate the initial deployment of infrastructure, the universal service obligations are transient, so optimal timing becomes an important issue. Both of these differences are addressed below.

The need for flexibility may be even more acute in the context of broadband infrastructure. One key to minimizing infrastructure costs is to exploit economies of scale and scope, which vary with technology choice, region, and year (Peha 1999). Economies of scale depend heavily on the area defined in the obligation. Phone companies want obligations with boundaries that match those of existing telephone providers. Terrestrial wireless providers want to combine areas that can easily be served by the same hilltop transmitter. Satellite providers are happy to serve remote areas, but do poorly where buildings and terrain make it difficult to deploy suitable satellite dishes. Regions have different combinations of current and potential providers, so each region has different needs. The only way for a policymaker to establish optimal obligations is to design implicitly the future networks of all possible providers. This effort in central planning has little chance of success.

As shown with examples in Peha (1999), bundling obligations in ways that do not take advantage of economies of scale can vastly increase costs, and, in the process, require far greater subsidies than would otherwise be necessary. This is one reason why the level of competitive bidding seen in reverse auctions in other countries is sometimes far below the level that policymakers hoped for or expected.

There are also important economies of scope. Some approaches can provide cost-effective combinations of broadband and some other application, where this application might be paid TV, fixed phone service, mobile phone service, paging, meter reading for electric power systems, or soil sensor reading to support advanced agricultural techniques. This combination can make the overall system financially sustainable. Which combination works will depend on the needs of the region, and the availability of other providers. Such circumstances are hard to predict when obligations are established through central planning. Allowing firms to trade obligations gives them the flexibility to assemble the collection of obligations they want.

The process begins with a reverse auction in which the winner accepts the obligations specified before the action in return for a subsidy that equals the winning bid. As others have proposed, those obligations relate to making broadband services available to a specified number of potential customers in a specified region. Differences include the fact that those obligations are fully tradable, and that each obligation takes a more complicated and therefore more flexible form. There are two components to an obligation: first, what must be done, and second, when it must be completed. Thus, there are two components to a universal service obligation: a *milestone* to achieve, and a commitment to meet a specific deadline. Because milestones and commitments are separated, when one of a firm's deadline is reached, this firm is free to decide which of its milestones will be met. This gives the firm great flexibility, which is compounded by the ability to trade deadlines, milestones, or both in an open market. This flexibility never interferes with steady progress towards ubiquitous broadband availability, because some important milestone must be met every time a deadline is reached.

Milestones take many forms. All these forms should refer to the availability of services rather than their underlying technology, and thereby remain technology neutral. Milestones should be clear and unambiguous. Milestones should be based on technical capabilities rather than on factors that depend on usage. For example, one milestone might be to make broadband Internet service available to at least ten thousand households in a precisely specified region, regardless of how many of those households choose to subscribe. It need not matter who actually provides the broadband services; if some provider other than the holder of the obligation builds the infrastructure, the obligation is still met. (In some cases, the holder of the obligation may offer this other provider assistance, if this appears to be the most cost-effective way of meeting the obligation.) There may also be milestones associated with making broadband available to entities other than households in this region, such as health care facilities or community colleges.

The biggest challenge in the example milestone above is providing an appropriate definition of broadband. The service must be of adequate quality to qualify, but what should that mean? Broadband providers typically advertise the quality of service that a user would get if no one else in the neighborhood were also trying to use the Internet at the same time, so users are sometimes disappointed that their actual service is worse than they expected from the advertisements. Similarly, an obligation to provide a peak data rate (in the absence of any other users) of 1 Mb/s would be insufficient, because this requirement would not prevent a provider from forcing thousands of users to share that 1 Mb/s capacity. Moreover, the most obvious way to deal with the problem of misleading advertising of broadband services in other contexts cannot be applied directly for tradable obligations. In an area with multiple providers from which to choose, a good option is to give consumers information about average rather than peak performance so they can make an informed choice. Although this is technically more difficult than it sounds, there are efforts under way to figure out how to do this. However, providers cannot be expected to accept a tradable obligation if they cannot estimate the costs of meeting that obligation; a requirement based on average performance depends on how users behave, which is difficult to predict. If an atypically large number of consumers in the same community happen to decide to make frequent use of Internet videoconferencing, then average performance will be well below what was reasonably expected. A provider should not be punished for this unforeseeable outcome.

Thus, the definition of broadband that a provider is required to meet must be stated in terms of technical capabilities that do not depend on actual usage.

Nevertheless, those requirements must be more detailed than what one typically sees in today's advertising. There should be some requirements on peak performance, i.e., what will be provided in the absence of congestion from other users' traffic. For example, broadband might require peak upstream and downstream data rates per user of at least 0.5 Mb/s each, a combined upstream and downstream rate of at least 1.5 Mb/s, and minimum latency from user to Internet backbone of 20 ms. There must also be requirements for shared resources that depend on the number of users who are sharing. For example, it might be specified that an upstream link that is shared by thirty or more customers must have a capacity of at least 50 Kb/s times the number of customers served. Thus, if no more than 20 percent of users are transmitting at any instant each customer is guaranteed at least 250 kb/s upstream on average. However, if the number of active users is unexpectedly high, this does not prevent the provider from meeting its obligations.

Other technical measures of service can also be embedded in the definition of broadband. Most importantly, some kind of availability requirement is useful. This is particularly important for wireless systems, which are vulnerable to weather, especially if designed with inadequate safety margins as a way of cutting costs. For example, it might be specified that a household is only considered served for the purpose of meeting the tradable obligation if broadband Internet is available to that household at least 98 percent of the time, averaged over a year.

Note that all of the requirements above are stated as minimums, thereby allowing a provider to go beyond. For example, a provider must serve a certain number of households, but is not precluded from serving businesses, or public safety agencies, or fixed sensor devices, or anything else that enhances the business case. This can only make an endeavor more financially sustainable, and reduce the amount of subsidy required. Similarly, the provider must provide at least the specified data rate, but it can provide more, and with any technology it chooses, so there is nothing to discourage technological advances. This has not always been the case for past universal service policies designed for telephony, where switching technology and adding nontelephone services might make a provider ineligible for subsides (Benton and Taglang 2007; Frieden 2005).

Obviously, consumers care about the price of services, as well as quality. It may therefore be worth establishing an upper bound on prices that a provider who accepts a subsidy can charge. However, there is an inherent trade-off in setting this price. A lower limit obviously makes this service more affordable, but lowering revenue projections for those who are considering a bid in the reverse auction increases the subsidies that these firms will demand. In effect, to set a lower limit is to subsidize service with taxpayer dollars for all customers. In general, it is better to focus on using tradable obligations to make the service available to all. If affordability proves to be an issue, that issue can be dealt with using a more targeted solution in the future. With or without limits, providers will not want to set rates so high that they discourage consumers from subscribing.

One almost-costless way to improve affordability in a more targeted way than a price cap is to make it easier for providers who accept tradable obligations to charge lower prices for those who the government determines through some form of means testing are low-income households. For example, any household that is eligible for the lower Life Line (FCC 2008e) prices for telephone service might also be eligible for a lower price for broadband.[6] Even if providers receive no subsidy for offering a lower price to low-income households, it is probably in their best interest to do so. After all, the marginal cost of serving one more household is small, and many low-income households would

6. This would include those with household incomes less than 135 percent of the federally established poverty line, and those that are eligible for one of a number of other federal programs (FCC 2008e).

not subscribe at all without a price break. Thus, by serving low-income households and no one else at a lower price, the provider increases its revenues from low-income households without reducing its revenues from high-income households.

Once the milestones are fully defined, they must be combined with appropriate deadlines. With the policies of the past, a typical build-out requirement might mandate that specific milestones in every region be completed by specific dates. However, giving providers greater flexibility would improve efficiency. Investment could take place more quickly on some fronts than others to maximize economies of scope and scale. The national interest is served as long as providers are making overall progress at a reasonable rate. Thus, we might require that industry meet a specific number of milestones each year without specifying which ones will be met. There therefore should be a set of commitments outstanding, where a commitment requires that at least some milestone be met by the associated deadline. This deadline may differ from one commitment to another. If the number of outstanding milestones exceeds the number of outstanding commitments, then the government is implicitly allowing industry to achieve the milestones that cost the least, without meeting them all. For example, if each milestone requires bringing broadband to ten thousand new homes, this policy would specify the number of homes gaining access to broadband each year, without specifying which homes gain access first.

Consider a firm with five milestones and five commitments. The firm is free to match each commitment with a milestone in any way that the firm chooses, in accordance with its own strategy for infrastructure expansion. If the firm has not successfully met the requirements of any milestone that it currently holds when a commitment is due, then that firm will be fined. Commitments are therefore liabilities, because they obligate a firm to either pay fines or invest capital to avoid those fines. Milestones are assets: one needs to meet a milestone in order to avoid paying a fine.

Firms are free to buy, sell, and trade milestones and commitments, in any combination. Thus, a firm that cannot meet the deadline associated with a given commitment may pay another firm to take that commitment. This exchange could bring capital to another firm that has a more aggressive expansion plan. For example, a nationwide system serving both public safety and the general public that is still several years from operation might seek out later commitments, whereas firms that are expanding aggressively accept the earlier commitments, for a price. Firms would also be free to exchange milestones, allowing each to put together a portfolio of obligations that can be met efficiently. Where there is an economy of scope a firm will seek to either obtain all or divest all complementary obligations. To make it easier for firms to find the trading partner they desire, a registry of all outstanding obligations would be available to the public.

If industry is free to select which milestones to meet at a given commitment deadline, the milestones should be of comparable social benefit. For example, each milestone might correspond to making broadband Internet available to a comparable number of households. If this is not the case, a weight might be added to reflect the estimated social value of each milestone, which in this case reflects the total number of households. If milestones are introduced corresponding to other types of facilities, such as community colleges, then guidelines should be established stating that the social value of offering broadband to a community college generally equals the social value of offering broadband to some number of homes. Commitments would also have weights, indicating how much must be accomplished by the given deadline. The sum of the weights of all milestones should equal (or possibly exceed) the sum of the weights of all commitments.

What if the regional boundaries associated with a given milestone are not conducive to minimizing cost? With regulator approval, a firm might divide a milestone into two parts such that the sum of the weights equals that of the original milestone. The regulator will ensure that the relative weights assigned to each piece are reasonable. Commitments can also be divided—although regulator scrutiny is unnecessary in that case—provided that the total weight does not change.

Because firms are trading broadband service obligations (liabilities) rather than emission permits (assets), there is a danger that a firm with many outstanding obligations could go bankrupt. Indeed, in the absence of some protection, this is a tempting strategy for borrowing money. A company could raise money by accepting many universal access commitments, with no intention of building telecommunications infrastructure. The company would later either repay the money by paying another provider to accept the commitments, or it would simply declare bankruptcy.

A simple requirement that a firm must have at least as many milestones as commitments might curb the most flagrant abuses. As further protection, the subsidies a firm might receive by participating in reverse auctions would be limited commensurate with the ability of the company to incur debts. Thus, a start-up company or small nonprofit cooperative might win the obligation to serve a community, but only a large established organization could win the obligations to serve many communities across the nation. Of course, a financially unstable company could still acquire many universal service obligations in after-auction trading. To prevent such a firm from nullifying these obligations, regulators can require that, in the event of bankruptcy, obligations revert to the previous owner. Thus, when universal service obligations are transferred from one party to another, the former essentially provides bankruptcy insurance for the latter.

It is possible to auction tradable obligations in combination with tradable resources, including valuable spectrum resources. We have discussed above the importance of making more spectrum available. Some (but not all) of that spectrum may require a license. In such cases, a tradable spectrum license might be bundled with tradable obligations in the same auction. In this way, universal service policy and spectrum policy would become intertwined. An auction winner who wants to build a wireless network can use the spectrum, whereas one who does not can indefinitely lease out the spectrum in a secondary spectrum market (FCC 2004).[7]

4.3. A Role for Local Government

Local communities and local governments can have a significant stake in the availability of broadband infrastructure. Indeed, this is driving some of the current interest in city-owned wireless broadband networks (Peha 2008b). Many rural communities have brought new broadband services to their city with a WiMAN, sometimes with substantial involvement from city government and sometimes without. Indeed, difficulties in WiMAN deployment in large cities such as San Francisco and Philadelphia (Breitbart 2007) have distracted many analysts from the successes in much smaller cities and towns. This movement in its current form may be part of the solution to bringing broadband to the unserved, and it also offers lessons for the approaches that address the problem over larger regions, such as the systems of tradable obligations described in §4.2.

As described in §3, communities can benefit from the availability of broadband, including members of the community who are not Internet users. The WiMAN deployments that most obviously deserve financial support from city governments are those that make it possible to make government services more effective or less expensive, as discussed in §3. Note that in these cases city government may come to depend on WiMAN availability. As a result, they have a particular interest in ensuring its long-term viability, which can be problematic when the system is in the hands of an unstable start-up.

In other cases, the WiMAN serves some broader policy objectives and is part of a larger effort to

7. In this context, *indefinitely* means unless and until the FCC takes the spectrum back, which is always possible under U.S. law.

achieve those objectives. For example, revitalization of the downtown area in Pittsburgh (Peha 2008b) has long been a stated objective of community leaders, including those in city government, local businesses, and prominent nonprofit organizations. There has been a concerted effort to improve entertainment offerings, housing, transportation, parking, and other factors that might convince Pittsburghers and tourists to spend more time and money downtown. Adding a WiMAN to serve downtown Pittsburgh was one more way to achieve these goals.

The first lesson from the WiMAN movement to date is that policymakers should stop inhibiting its growth. There are now laws in a number of states (Tapia and Ortiz 2006) such as Pennsylvania (General Assembly of Pennsylvania 2003) that limit the ability of a local government to embark on this path. The nominal rationale is that local governments should leave this task to the commercial providers rather than meddle in the market. Although the loudest supporters of these prohibitions tend to be commercial providers that are protecting their own market share, this argument is not without merit; there are communities where city governments do a great disservice to their citizens by spending limited resources in this way and by trying to do something that commercial companies can do better. Nevertheless, for state legislatures to constrain all city governments for this reason is as sensible as Congress prohibiting all local governments from purchasing snow plows, with a declaration that "it would be foolish for city government in Las Vegas to buy snow plows, so we should remove this option from Minneapolis as well." Congress can and should prevent states from these blanket prohibitions, and let local leaders who are accountable to local voters make this decision. (Congress has previously considered legislation that would prevent States from imposing prohibitions on local governments, while also seeking to prevent local governments from favoring one provider over another [Boucher and Upton 2007].)

There will still be many communities in which local governments lack the ability and resources to make a WiMAN available. The hardest part is deployment. For example, in our estimates for a citywide WiMAN in Pittsburgh, the cost of deployment was roughly three times annual operating expenses (Peha et al. 2007). Moreover, unlike operating expenses, there are no revenues to reduce the burden of deployment costs.

If a federal system of tradable obligations were created, local governments should still play an important role in this process. At minimum, local governments and large institutions should be encouraged to make commitments even before the auction to be customers of a new broadband system, if one is indeed created. In this way, local governments can guarantee *before* a reverse auction that they will be customers of broadband if and when it becomes available.

As discussed in §3, in many cases a broadband network can allow city government to cut costs, improve services, or both. Rather than build their own communications infrastructure, they might become an anchor tenant for a network that also serves the public, thereby improving that network's chances of becoming financially sustainable. They might also encourage large institutions in the region to do the same, effectively aggregating and guaranteeing demand. This guaranteed revenue stream can do much to attract providers. In return for this guaranteed business, local government may need assurances that the service will be available in the long term. Thus, when the provider decides to participate in the reverse auction, it must agree that federal government will inherit the infrastructure should that provider go bankrupt. The federal government can then either make this infrastructure available to the winning bidder of a new reverse auction, or simply give the infrastructure to a local government.

Moreover, local governments with particular needs and preferences for a new broadband infrastructure can define their own obligations, with milestones tailored for their needs. For example, they may want to ensure that schools and fire stations are served. These milestones may be combined with others in the same reverse auction, or distributed separately. This can be done through traditional contracting, of course, before or after the reverse auction. Alternatively, a city government may craft a new milestone and commitment that will be part of the package that is auctioned or add weight to existing milestones of particular importance, and contribute funds toward that auction for this privilege. In this way, the city attracts more bidders, and ensures that its objectives will be considered from the beginning.

Even if local government agencies will not become major users of a broadband network local government can play a critical role by eliminating obstacles to build-out (e.g., approving right-of-way requests), and by making essential resources easily available to all providers. Perhaps the most important such resource is sites suitable for wireless transmitters. These sites must be reasonably safe from theft and vandalism, have electric power available, and be within communications reach of many households. Local government often controls access to many useful antenna sites, such as the rooftops of government buildings, and light poles. Payments for antenna sites can be a significant part of wireless broadband network's annual operating expenses (Peha et al. 2007). Wherever possible, current and potential broadband providers should be assured even before the reverse auction takes place that these sites will be available to any provider at little cost on a nonexclusive nondiscriminatory basis. Some cities also have other resources that, if made available to broadband providers at reasonable prices, would greatly decrease deployment costs. Examples include power sources, and communications networks that are suitable for backhaul, which may have been deployed for some other purpose. In effect, the city would be making an in-kind contribution for the reverse auction.

Making resources of this kind available on a nonexclusive basis is cost effective for two reasons. First, it allows city government and the broadband provider to share a valuable resource, without duplicating the cost. For example, if both the broadband provider and the city need a power generator in a remote area, there is no need to build two such generators. Second, it increases the chances that competition might emerge by allowing competing providers to avoid duplicating the cost of such resources when sharing is possible.

4.4. Obligations of Subsidized Monopoly Broadband Providers

A system of tradable universal service obligations is likely to yield a monopoly broadband provider in many communities. After all, an area that can sustain multiple broadband providers should not need a reverse auction to attract the first provider. Like any monopoly, it may charge somewhat more for its core service than would be possible in a competitive market; within reason, though, this is not a serious problem. Indeed, expectation of these somewhat higher monthly fees will help justify the cost of infrastructure deployment, and thereby reduce the needed subsidy.

However, thanks in part to the relatively recent commercialization of powerful technology like deep packet inspection and flow classification (Peha 2006), broadband providers have the ability to do things far worse to customers than raising prices, and those broadband providers that are monopolies could also have the incentive. Unfortunately, a monopoly broadband provider has the ability to become a powerful information gatekeeper for a community.

The first problem is that the broadband provider can further increase profit by limiting a customer's access to specific content or applications (Peha 2006). Consider for example a broadband provider that also offers cable TV services. This provider would be happy to sell customers the ability to surf the web and send e-mails, but may want to prevent customers from using the Internet to download high-quality thirty-minute entertainment videos, because this threatens the company's core business. Similarly, a phone company would prefer to block

Internet telephony, i.e., VOIP services, or simply to degrade quality of service for VOIP or add extra surcharges to the point where customers prefer traditional telephone service. This is not merely a theoretical possibility. There are devices on the market designed to help ISPs do this (Peha 2006).

In the examples above, companies use their control over the broadband connection to gain advantages in the market for other services they offer, such as telephony. Moreover, monopoly providers can leverage their control over the network to force consumers into paying what amounts to monopoly prices even in competitive markets. For example, if consumers in a competitive market pay $1 per downloaded song, but a broadband provider determines that its rural customers with their limited options will pay $2 per song, the provider can add an extra $1 fee for each downloaded song, regardless of which music service actually provides that song. This $1 fee does not reflect what it costs the broadband provider to offer the service. Indeed, the provider would presumably charge nothing extra to download a relatively unpopular text file of identical size and therefore with identical impact on the network. In economic terms, a provider that can perfectly discriminate among uses and identify what a customer is willing to pay can force consumers to pay monopoly prices, and thus shift the benefit consumers get from the Internet (consumer surplus) into benefit for the monopoly provider (profit).

Second, there are also issues of free speech. Will a profit-seeking broadband provider try to limit its customers' access to some content? There is much disagreement on this, because such actions would often diminish the provider's own profit, but there are some cases where it is plausible (Peha 2006). For example, a Canadian ISP has been accused of blocking access to a labor union's website during a period of conflict between this union and the ISP (Windhausen 2006).

The FCC has adopted network neutrality principles to address such problems. Under these principles, consumers have a right to access the legal content of their choice, to use the application of their choice, and to attach the device of their choice (FCC 2005a; Powell 2004). As of this writing, the exact meaning of these somewhat vaguely stated principles is still being determined in ongoing FCC proceedings (FCC 2008a). Related legislation is also pending in Congress (Markey 2008). The network neutrality debate is a complex matter that falls largely outside the scope of this paper. It is worth noting, though, that the issue is somewhat different within the bounds of tradable obligations. First, while some believe that there will be sufficient competition among broadband providers in most parts of the country to deter these potential abuses of market power, this will not be the case in areas covered by universal service obligations. Second, while some argue that government should not limit what a commercial broadband provider does with a network it has paid to construct, this argument does not apply to providers who explicitly request government subsidies by participating in a reverse auction. Thus, there is greater reason to impose limits on broadband providers who accept universal service obligations than to impose limits on other firms.

At the same time, policymakers must resist the temptation to impose overly broad constraints on broadband providers. Although consumers may benefit from modest constraints on the extent to which providers can discriminate, onerous constraints could deter providers from bidding, or induce less aggressive bidding, and therefore higher subsidies. Even worse, overly broad constraints could undermine a broadband provider's ability to manage its network and provide cost-effective services (Peha 2006). The most important examples are security related. Networks must have the ability to discriminate against some applications when those applications happen to be viruses. They must be able to discriminate against some users when they determine those users are launching a denial of service attack on other customers. Consumers may also be grateful for discrimination based on content, when that content is spam. There are also good reasons for broadband providers to discriminate during periods of congestion. If done well, this will allow applications with strict quality of service requirements like VOIP to remain unaffected, while traffic such as e-mail that does not require the same quality of service is delayed. Unfortunately, some proposed network neutrality policies would have the effect of prohibiting some highly beneficial uses of discrimination (Peha 2006).

There is still great controversy over what restrictions should and should not be imposed on broadband providers throughout the nation (FCC 2008a); the more general questions are largely beyond the scope of this paper. However, when targeting government funds for the creation of monopoly providers, it is reasonable to specify some lightweight limitations on discrimination among the obligations of those who accept the subsidy. Even if the FCC chooses not to impose significant constraints on broadband providers as part of its network neutrality policy, firms should accept some constraints wherever they accept subsidized universal service obligations. Put another way, the broadband they provide cannot meet the requirements specified in a milestone if the provider engages in certain discriminatory practices.

At the same time, these constraints must be modest. For example, while outright blocking of traffic might be prohibited in most circumstances, blocking must be allowed when it is done to address legitimate security concerns. Moreover, providers should be allowed to provide different quality of service for different applications or different users. However, if one consumer, content provider, or applications service provider has access to a given quality of service at a given price, then unless there is a good (e.g., cost-based) reason to the contrary, others should be able to get that comparable quality of service at the same price. (See Peha 2006 for more detail.)

5. Implications for Current Universal Service Policy

Some have suggested that the best way for the United States to increase penetration of broadband is simply to redefine existing universal service policy to include broadband. This paper argues for a set of policies focused on a more specific problem: to make broadband available to more American households, whether or not those households choose to subscribe. The existing universal service fund (USF), as forged in the 1996 Telecommunications Act, is not well suited for this purpose. The USF is actually a family of programs, intended to serve schools and libraries, rural health care facilities, low-income households, and high-cost rural areas. The purpose of the latter program is to ensure that prices for telephone service are comparable in both rural and urban areas (U.S. Congress 1996), under the implicit assumption that telephone service is available in both. Consequently, the USF subsidizes monthly services, and will do so for the indefinite future. We argue that for broadband, the more appropriate universal service objective is to bring service to unserved communities. For this objective, we need a different approach.

Nevertheless, current discussions about reform of the USF may create opportunities to address broadband, perhaps through a system of tradable obligations. Universal service policy in the United States requires a major overhaul in the near future, in part because the USF is no longer financially sustainable. The money paid to rural providers has been rapidly increasing. Many new telephone competitors, often using wireless technology, now receive USF subsidies to serve rural areas. Indeed, subsidies for these new competitors have grown from negligible in 2002 to more than $1 billion in 2006 (Martin 2007a, 2007b), whereas the subsidies flowing to existing wireline providers have remained roughly constant at around $3 billion per year (Martin 2007a, 2007b). Meanwhile, the money flowing into the fund from taxes on telephone service has been stagnant at best. Moreover, incoming funds may soon decrease as users switch from services that incur a USF tax, such as traditional wireline telephone service, to new services, including VOIP, that do not incur that tax. The FCC has taken some measures to temporarily reduce expenses (FCC 2008c), but more fundamental changes are needed to preserve the goals of the fund while remaining solvent. Among other things, these measures must limit expenses in rural regions with multiple telephone companies by reducing the number of fund recipients or reducing the amount paid to each recipient, or both.

It is also worth noting that it is not clear how much the additional money spent for universal service has actually made telephone service more universal. While one stated goal of the 1996 Telecommunications Act which created the USF is to ensure that consumers "in rural, insular, and high-cost areas, should have access to telecommunications and information services . . . at rates that are reasonably comparable to rates charged for similar services in urban areas" (U.S. Congress 1996, §254 (b) (3)), the more important goal is to make sure as many U.S. households as possible can afford telephone service. However, the number of households with one or more telephones (including cellular phones) has remained fairly stable for the past fifteen years at roughly 94 to 95 percent (Belinfante 2008), with the remaining households still out of reach. Moreover, some recipients of subsidies probably would still find telephone service affordable if they paid more. For example, at present, residents of a Pittsburgh neighborhood where the houses sell for about $50,000 must help pay for phone service in multi-million-dollar homes by the ski slopes of Vail. This does help to ensure that rural and urban areas pay comparable prices for phone service, but it certainly does not help to make phone service affordable to all. Perhaps future universal service policy will take property values or some other measure of wealth into account, allowing rural providers in select areas to cover more costs from wealthy households and less from government subsidies.

As policymakers somehow reduce the funds spent in rural areas for telephone service, there may be a unique window of opportunity to increase the funds spent in rural areas for other purposes. This may be an ideal time to introduce a system of tradable universal service obligations for broadband.

It is also important for any reform of the USF fund to allow any greenfield broadband networks built out in unserved communities to at least compete for traditional telephone universal service funds, even if those new broadband networks are entirely IP-based (Benton and Taglang 2007; Frieden 2005). This may be cost effective for the provision of both broadband and telephone services.

6. Conclusions

Broadband infrastructure has spread through much of the United States, but some communities and perhaps a third of rural households have been left behind, which places these communities and households at a significant disadvantage. Indeed, it is not just that these communities lack a valuable resource that others have—the national trend toward broadband has left the unserved communities worse off than they were before, as companies, government agencies, and individuals increasingly assume that consumers and citizens have broadband. Moreover, the rest of the nation suffers from its inability to communicate via broadband with citizens in these unserved communities.

Changes in policy can help bring broadband to more of these communities. We should start by collecting much better data on precisely who is unserved and where, so we can better evaluate the cost and effectiveness of various approaches to expanding broadband infrastructure.

Contrary to some proposals, there are methods that are more cost effective than simply treating broadband like telephone service in today's universal service policy. We need policies that take advantage of market forces to the maximum extent possible, that are narrowly targeted on any market failures, and that are sufficiently technology neutral to remain effective as both technology and markets change.

To meet these objectives, this paper has described three interrelated policies that can initially be pursued in parallel. The first is to make spectrum more widely available within a framework that is appropriate for the technology of wireless broadband. Examples include making use of the white space in TV spectrum, making better use of spectrum currently allocated to public safety, and making an inventory of government use of spectrum publicly available as the first step to identifying bands that could be shifted to public use. Both the FCC and the NTIA have important roles to play in these policy changes. Simply making spectrum available may be sufficient for some unserved areas, whereas others may need financial assistance.

For those communities that do need financial assistance, subsidies should be disseminated to help cover the *one-time* cost of either upgrading existing networks to support broadband services or building out new broadband infrastructure. These subsidies come with obligations to make broadband more widely available. To minimize costs and subsidies, broadband providers should be given extensive flexibility with respect to how they meet obligations, and the order in which these obligations are met. This can be done through a system of reverse auctions and tradable obligations, through which each provider can acquire the portfolio of milestones and commitments that maximizes profits, thereby reducing the subsidies required. Moreover, further trading allows firms to adjust their portfolios over time, thereby increasing the chances of long-term financial sustainability. Firms that accept these tradable obligations and associated subsidies will also agree to modest limits on their use of discrimination, thereby limiting their ability to use their monopoly status to undermine the value of the Internet to consumers. This policy might first be tried on a small scale as a pilot. Current efforts to reform the USF for telephony may also lead to opportunities for a much larger version.

Finally, policies should be established that allow and encourage local governments to play a role, because specific needs and objectives can vary somewhat one community to another. The first and easiest step is simply to remove current impediments on what local government can do with respect to broadband infrastructure. More generally, if a system of tradable obligations is established, then local government should be encouraged to commit to being a broadband customer and to making useful resources available to providers on a nonexclusive basis. Moreover, local government agencies that use broadband services should be given some protection in case broadband providers fail, and these agencies should have the ability to influence some of the provider's obligations.

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Acknowledgments

I thank Ryan Hallahan, a Ph.D. student in the Department of Engineering and Public Policy at Carnegie Mellon University, for his work to produce Figure 5 of this paper.

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