# Broadband Demand and Wireless

Tom Lookabaugh, Scott Savage, and Douglas C. Sicker

Interdisciplinary Telecommunications Department
University of Colorado
Campus Box 530, Boulder, CO 80309
Corresponding Author: Tom.Lookabaugh@colorado.edu
+1 (303) 492-0429 (phone) +1 (303) 492-1112 (fax)

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***Abstract*- Notwithstanding the inconclusive status of the public policy debate on intervention in support of broadband Internet access, wireless broadband can play an important role in the overall adoption of broadband in the U. S. Results from a recent consumer survey of broadband demand attributes informs here a discussion of wireless broadband, including the key role of reliability, wireless as an element of government competition policy, spectrum policy reform, fostering of novel decentralized access services, the role of wireless in closing the digital divide, the use of mobility to expand applications' user communities, and wireless broadband in public safety.**

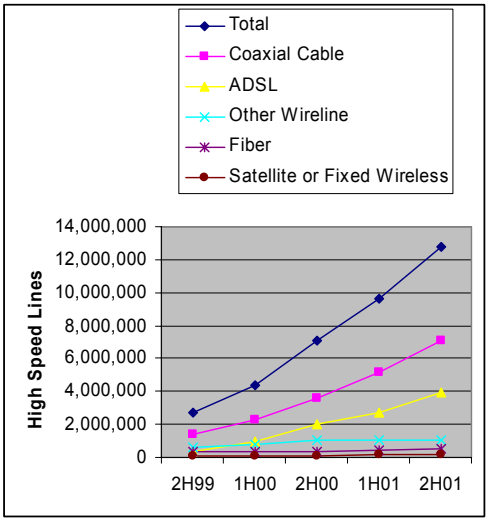
## I. The Broadband Policy Debate

Broadband Internet access suffers from a multiplicity of definitions [1]. Usually, bit rate is taken as the defining characteristic with definitional rates ranging from 200 kbps to 100 Mbps. Alternatively, broadband is sometimes defined in terms of the applications it enables, or other characteristics than bit rate (such as "always on" connectivity or low latency). We will use the U. S. Federal Communication Commission's definition of "high speed lines" – at least 200 kbps in at least one direction. This definition fits many actual and proposed cable modem, DSL, fixed wireless, and satellite Internet access solutions.

Although exact capabilities vary by service provider and the type of service purchased, broadband Internet access is often used for web browsing with quick response times, transfer of crisp video images and CD quality audio files over the Internet, quick downloads of large files, playing real-time interactive games with people in different locations, and providing efficient access for others on the Internet to large audio, text and video stored on local PCs or other devices.

A majority of Americans use the Internet; however, a smaller fraction is using broadband, on the order of 15% of households [2]. The U. S. public debate on broadband demand policy revolves around two main positions: (1) broadband demand is growing too slowly for the nation's good (implying that intervention is in order) or (2) broadband demand is growing at a reasonable rate (no intervention is in order). Figure 1 shows the number of "high speed lines" from FCC data for various access technologies.

**Figure 1. High Speed Lines (greater than 200 kbps in at least one direction) in the United States** [3]**.**




Clearly, subscription has been growing, particularly for cable modem and DSL technologies. Fixed wireless and satellite have relatively low penetration.

The rate of growth is a subject of concern, however. The semester over semester growth rate in Figure 1 dropped from approximately 60% in both semesters of 2000 to approximately 35% in both semesters of 2001. The fact that growth rates (expressed as increase in subscribers divided by subscribers at the start of the period as in the above percentages) decline during the adoption of a technology should not by itself be a cause for alarm – indeed the most commonly used mathematical model for adoption, the logistic or "S-shaped" curve, is

characterized by continually declining growth rates throughout the entire adoption process. However, the decline from 60% to 35% growth rate is substantial and exceeds any reasonable fit for simple diffusion models. The most popular explanation for this decline in growth is rising prices associated with a decline in competition at the end of the technology bubble of the late 90's [4, 5].

A second point in the wireless policy debate is the widespread availability of broadband relative to subscription. FCC data shows that broadband is available in 98% of zip codes [3]. Our own survey suggested that at least 76% of our respondents' households believed that they had access to broadband (Table 3 below). Yet a much smaller fraction (26%) subscribe. Again, though, this should not in itself be a source of concern; most consumer technology products are adopted at a slower rate than they are available to consumers since many other issues than simple availability pace adoption. The evolution of prices is surely a factor (many consumer technology adoptions are associated with falling prices over time, unlike the recent flat to increasing evolution of prices in broadband), as well as externalities such as network effects (the value of subscription rises as others subscribe) and complementary product and service effects (the value of subscription rises as products and services enabled by broadband become increasingly available).

A third point is the relative adoption rate of broadband in the early adoption period compared to consumer innovations such as telephone, television, cellular phones, compact disk players, etc, many of which took substantially longer to reach the 15% penetration level (suggesting that broadband adoption rates are, in fact, historically quite robust). These comparisons are challenging, though, since consumer technology adoptions have been accelerating and there are many specific factors that could differentiate the adoptions of these different technologies.

Overall, it is difficult to draw a strong conclusion about the adoption rate of broadband; subscription is steadily increasing although the decline in growth rate suggests some abnormality to the adoption process.

Regardless of the conclusion on whether the growth rate is "normal" or not, proponents of intervention [6, 7] point to the potential benefits of accelerating adoption in terms of economic growth (based on improved utilization of information technology), international competitiveness (some other countries have substantially higher penetration than the U. S. [8]), and a number of applications that are enabled or enhanced by broadband, and are of economic benefit or other societal benefit (e.g., security, health, education). Some express a need to identify a "killer application" for broadband [9, 10]; that is, one so compelling that by itself it can also motivate the purchase of broadband. But, its not clear that such a broad platform needs a killer application and indeed most adopters are satisfied while mainly using, to first order, the same applications as dial-up users, albeit with greater convenience (Table 4 below). The result, then, is a general consensus on the desirability of broadband adoption itself without a consensus around the desirability of expensive interventionist policies to accelerate adoption.

## II. BROADBAND USAGE AND ATTRIBUTES

To better understand the state of residential demand for broadband, we conducted a nationwide mail survey of US residences during September and October 2002 [1, 11]. In particular, we sought to investigate consumer awareness of Internet access service, profile residential Internet access and use, and gain insight into how important "always on" connectivity, cost, rate, installation and reliability attributes are in a household's choice of service.

Survey data provide a profile of the representative household respondent. The average respondent is a white, 50 year old male, with a two year degree at a college or technical school, who resides in a household with 1.7 other members. He was employed last month at a location outside of the home, and has annual household income of $71,934. A description of how Internet access varies by income, race, household size, age, education and employment status can be found in [11].

Here we summarize some of the results of this survey that either help describe the characteristics of actual and potential broadband users or illuminate issues of particular importance to wireless broadband.

### *A. Social Disadvantage*

The "digital divide" debate refers to the perceived gap in computer and Internet use between high and low income households, educated and less educated populations, white and minority populations, urban and rural areas, etc. [12]. Table 1 shows type of Internet access by various measures of social disadvantage. The percentage of respondents with no access is relatively high for less educated, senior, and lower income groups. Broadband access is low for less educated and lower income groups, and no lower income respondents have broadband access to the home.

**Table 1. Internet access by measures of social disadvantage**

| Disadvantaged groups | No access | Dial-up | Broadband |
|---|---|---|---|
| Less educated (high school or less) | 39.5 | 50.0 | 10.5 |
| Senior (age greater than 65) | 44.7 | 40.8 | 14.5 |
| Lower income (income less than $20,000) | 70.6 | 29.4 | 0.0 |
| Minority (non-white) | 22.2 | 63.0 | 14.8 |
| Women (women head of household) | 26.5 | 58.9 | 14.6 |
| Total (all households) | 28.3 | 51.5 | 18.8 |

*Note*. Cells are percent of respondents in the access category.

### *B. Computers and Telephones*

78 percent of all respondents have at least one PC or laptop in the home, while 32.6 percent have two or more PCs or laptops in the home. Table 2 presents a cross-tabulation of the number of computers in the home and type of Internet access for respondents with Internet access. Broadband Internet access is positively associated with the number of computers in the home. Further, 88.7 percent of respondents have at least one telephone line from the home, and 24.1 percent have a second line. The most frequently sited reason for a second line is "for dial-up Internet access – to free up the primary telephone line for voice calls" (48 percent of homes provide this reason).

**Table 2. Internet access by computers in the home**

| Computers in the home | Dial-up (*n*=214) | Broadband (*n*=77) |
|---|---|---|
| One (*n*=170) | 79.4 | 20.6 |
| Two or more (*n*=80) | 72.5 | 27.5 |
| Three or more (*n*=41) | 51.2 | 48.8 |
| Chi-square test for independence of the variables $\chi^2(2) = 13.55$* | | |
| Correlation coefficient for linear association between variables $\rho = 0.205$* | | |

*Note*. Cells are percent of respondents in the access category. * is significant at the five percent level.

### *C. Awareness of service availability*

Awareness of broadband service availability is relatively high for cable modem and DSL technology. Table 3 shows responses to the question "which ways of getting broadband access are available in your neighborhood." 15.3 percent of respondents replied "not sure" for cable modem, 30 percent for DSL, 68.1 percent for fixed wireless, and 64.7 percent for satellite. For fixed wireless, only 15.8% of respondents believe that fixed wireless access is available in their neighborhood; fixed wireless appears to suffer both from low availability and low awareness.

**Table 3. Awareness of broadband Internet access**

| Access technology | Available | Not available | Not sure |
|---|---|---|---|
| Cable modem (*n*=352) | 73.0 | 11.6 | 15.3 |
| DSL (*n*=333) | 57.7 | 12.3 | 30.0 |
| Fixed wireless (*n*=311) | 15.8 | 16.1 | 68.1 |
| Satellite Internet (*n*=317) | 27.4 | 7.9 | 64.7 |

*Note*. Cells are percent of respondents answering "available", "not available", or "not sure."

### *D. Internet Access*

71.7 percent of homes connect to the Internet. 71.8 percent of these homes access the Internet with a dial-up connection, two percent use WebTV, and 26.2 percent use a broadband connection. Survey data suggest that 18.8 percent of the population have a broadband connection at home. The most frequently sited reason for broadband Internet access is "speed is appropriate", followed by "I like the always on connection", and "to free up my telephone line for voice calls". The mean price per month for dial-up and broadband access, respectively, is $17.51 and $40.76, although to the extent a consumer does, in fact, surrender a second dial-up telephone line when switching to broadband, the cost of broadband becomes less onerous.

### *E. Internet Activity and Experience*

Broadband users are more active with 19.44 hours of online activity per week compared to dial-up users with 12.55 hours of online activity. Including home, school, work and other locations, broadband users have been going online for 3.48 years compared to 3.22 years for dial-up users. When asked whether they use a broadband Internet connection at any location outside of the home, 94.6 percent of all respondents (i.e., those with and without Internet access at the home) indicate they have used broadband Internet at either a cyber café, library, place of employment, school, friend/relative's house, or other location.

Internet activity data are obtained by asking respondents "how often do you and other household members do each of the following activities: email and IM; use search engines or purchase products; play games or gamble; share music files or photos; banking, trading stocks, or bill payment; and download movies to view on the PC." Table 4 shows Internet activity for "many times a week." Email and

IM, and search engines and product purchases are frequent activities for both dial-up and broadband users, which is consistent with findings from the BLS [2]. As suggested above by the number of hours online per week, broadband users are more active than dial-up users. The percentage of broadband users answering "many times a week" is higher for all Internet activities.

**Table 4. Frequency of Internet activity – "many times a week"**

| Activity | All | Dial-up | Broadband |
|---|---|---|---|
| Email & instant messaging | 71.4 | 68.5 | 79.7 |
| Search engines & purchase products | 37.8 | 29.5 | 60.8 |
| Play games & gamble | 21.0 | 17.7 | 30.8 |
| Share music file or photos | 10.1 | 6.8 | 19.5 |
| Banking, trading stocks, or bill payment | 9.8 | 7.4 | 16.5 |
| Download movies to view on PC | 1.0 | 0.9 | 1.3 |

*Note*. Cells are percent of respondents using the activity "many times a week."

### *F. Internet Access Attributes*

The "Internet Access Attributes" section of the questionnaire describes and informs respondents about Internet access attributes. Respondents consider their preferences for different attributes when answering the question "how important is (or would be) the attribute of Internet access to you." A single answer is selected for each question from the following choices, "not important", slightly important", "somewhat important", "very important", and "extremely important."

Table 5 shows the percent of respondents who indicate the attribute is either a very important or extremely important part of their Internet access. Speed, reliability, and always on functionality are clearly important to broadband users. Interestingly, reliability of service is also quite important for respondents with no access, dial-up access, and broadband access. This latter finding supports anecdotal evidence that consumers desire a service they can count on being available whenever they want to use it, with consistent speed (that is as fast as advertised), and any problems that do arise are immediately handled by good customer service.

In addition to asking respondents which attributes were important, we used conjoint analysis to estimate their willingness to pay for improvements in each of the attributes. The results were broadly consistent with their description of importance of attributes. In particular, willingness to pay for improvement in reliability was the largest across all the attributes and for both current users and latent users (dial-up users who live in areas where broadband is available).

**Table 5. Importance of attributes by Internet access**

| Attribute | All | No access | Dial-up | Broadband |
|---|---|---|---|---|
| Always on | 49.1 | 40.3 | 39.0 | 87.3 |
| Cost | 59.6 | 48.6 | 64.6 | 58.3 |
| Speed | 53.6 | 38.1 | 46.2 | 92.4 |
| Installation | 33.6 | 34.2 | 26.0 | 54.4 |
| Reliability | 66.3 | 52.0 | 64.1 | 89.9 |

*Note*. Cells are percent of respondents who indicate attribute is "extremely important" or "very important."

## III. WIRELESS AND BROADBAND

Wireless technology, applications, and business are a critical component of the overall broadband demand status and policy discussion. To date, wireless has not played a large role in broadband adoption but it can potentially be quite important.

### *A. Awareness*

Aside from low actual availability, most potential users are simply unaware of fixed wireless (unsure as to whether it is or is not available). While wireline providers have been communicating the value and availability of their offerings for several years now, wireless options will have to spend substantial effort creating basic consumer awareness. On the other hand, communities which have been educated about broadband by wireline providers (spill over from generic promotion campaigns) but which are underserved should provide quick yield from education and promotion campaigns for wireless and represent obviously attractive initial targets.

### *B. Attributes Relevant to Wireless*

Our survey on broadband demand provides some important information on broadband attributes for wireless. Not surprisingly, speed is a valued attribute of broadband. Interestingly, though, ease of installation is not highly valued by either current or potential users. Wireless businesses would be better off optimizing other attributes or their own cost to install over the perceived ease of installation on the user's part. Conversely, reliability is highly valued by current and potential users and is, in fact, more highly valued than speed. This has important and somewhat awkward ramifications for wireless systems and businesses. Wireless systems intrinsically share capacity among users; systems which take advantage of statistical usage patterns to increase user density will occasionally experience peak loading resulting in perceived reduction in reliability. This needs to be

carefully managed. The situation is more pronounced in unlicensed spectrum; here there is little ability to control even the number of users let alone their particular usage patterns. Moreover, wireless systems can also suffer capacity degradation based on physical changes in the environment (e.g., moving objects, changing topography due to construction or vegetation, weather conditions). Care needs to be taken in engineering systems so that wireless does not become associated with appreciably lower reliability from the users' perspective than wireline alternatives, unless cost advantages permit substantially lower pricing to compensate for loss in this valued aspect of service.

### C. *Inter-Modal Competition Policy*

The FCC and other government bodies generally support the idea that robust competition among telecommunications service providers is in the public interest. While some continue to advocate access to incumbents' plant by competitors within each access technology (intra-modal competition) [13], the FCC seems more oriented recently towards a focus on competition between competitors using different access technologies (inter-modal competition) [14]. As we noted in Section I, while there is general support for steps that would encourage more rapid broadband adoption, there is little consensus around an interventionist government policy, particularly an expensive one. Wireless can play an important role in facilitating intra-model competition and accelerating broadband adoption by creating a viable and widespread third platform (to compete with DSL and cable modems) without government subsidies. One possibility is through the emergence of innovative technology and business models in unlicensed spectrum (discussed further below). The other is through the effective use of traditional licensed spectrum; indeed notwithstanding the travails of various businesses attempting to offer Internet access in licensed spectrum, the continued evolution of technology and the presence of underserved communities suggest that fixed wireless access models in licensed spectrum could be viable, were it practical to license or sub-license spectrum in geographic regions more limited than Basic Trading Areas [15]. The viability of such businesses rests on policy and practice in licensed spectrum allocation.

### D. *Spectrum Policy*

Reform of spectrum policy is being touted by the U S government administration as a key component in its general support for broadband deployment and is a subject of a comprehensive current effort within the FCC [16]. The general notions are to increase reliance on market-based mechanisms to allocate spectrum, both through exclusive transferable spectrum rights, and through unlicensed spectrum commons, and adoption and reliance on new technology approaches which allow reuse of spectrum without impinging on incumbent spectrum licensees. Increasing the flexibility of access to spectrum is likely to have a strong positive affect on the role of wireless in broadband adoption. While technology, such as Software Defined Radios (SDR) and UltraWide Band (UWB), become more mature, it may well be the flexibility in government policy that determine their success.

### E. *Decentralization and Diffusion of Power*

Wireless, particularly in the form of IEEE 802.11b (Wi-Fi) networks operating in unlicensed spectrum, has shown the potential for novel, diffuse, and politically decentralized versions of network access that are hard to duplicate in wired configurations. Wi-Fi is most widely deployed as a local area networking technology, but public access is also expanding through creation of "hot spots." Although several traditional geographically diverse network service providers are emerging directly (for example, the recently announced Cometa Networks joint venture, www.cometanetworks.com) or as aggregators (e.g., Boingo, www.boingo.com and Joltage, www.joltage.com), a number of innovative alternative business models are also developing, including grass-roots cooperatives [17, 18] (albeit some such networks run into trouble with telephone or cable company backhaul [19]) and municipality installed networks, such as in Long Beach, California [20]. And technology and business models are co-evolving with the development of mesh-oriented 802.11 networks in which subscribers cooperate to carry their own signals and those of their neighbors [21]. Overall, these developments support the FCC's attempts to reform spectrum policy in favor of innovation and recent congressional moves to increase allocations of unlicensed spectrum [22]. But, challenges in unlicensed spectrum are also already emerging, as, for example, commercial hot spots and community grass-roots networks come into conflict [23].

Several commercial cellular providers are also looking at Wi-Fi as a means of extending their present cellular coverage and capabilities in hot spot areas. This suggests an interesting model; one in which a traditionally centralized service provider enters into a decentralized service. Such efforts could alter the grassroots networking efforts considerably, in that large service providers could come to dominate popular access areas. However, Wi-Fi, as an unlicensed service, requires that providers must contend with interference issues (important to perceptions of reliability as discussed above). Control of key hot spots through exclusive arrangements with property owners, such as a mall or airport, may limit

the interference and provide essentially a default control of the spectrum. In this way, the battle might be won by property boundaries rather than spectrum ownership.

### F. The "Digital Divide" and Universal Access

Although broadband is widely available, it is least available in rural and economically disadvantaged areas (see Table 1 regarding disadvantaged populations). Wireless can play a role in economically extending access to broadband to these communities. Satellite based access is obviously of importance to rural subscribers, although the combination of relatively high cost of satellite services and relatively lower adoption rates among this population mean that satellite based systems are having little impact so far on overall subscription rates. Fixed terrestrial wireless systems could play an important role in some rural communities, although perhaps requiring supportive government policy [24]. Altruistically motivated cooperatives and municipally supported networks may also help in reaching disadvantaged urban communities; an example of the former is NYCwireless in New York City [25]. The advent of more flexible Universe Service Funding (USF) measures could aid in the development of wireless services for rural and economically disadvantaged based on cross-subsidization between users.

### G. Mobility and Network Externalities

Many broadband applications exhibit network externalities: they become more valuable the more users there are. All users benefit, then, if wireless can incorporate mobile users into an application's user community. In fact, each of the major types of applications usually touted as important to broadband [1] is advantaged by mobility in some way:

*Entertainment* (including games) – consumers have abundantly demonstrated their desire to consume entertainment content while mobile.

*Education* – some forms of education can substitute for entertainment for mobile consumption; in other cases wireless delivery of broadband might facilitate delivery of education to disadvantaged communities (as part of closing the digital divide).

*National Security and Digital Government* – some applications, such as public safety (discussed further below) benefit substantially from mobility.

*Teleworking* – like consumers, business users have historically demonstrated a high desire for mobile access.

*Telehealth* – some applications, such as emergency medical teams, would benefit from mobile broadband access, and others, as with education, could benefit from improved access to disadvantaged and rural communities.

### H. Public Safety

Integrating wireless data access for public safety agencies has become a national priority [26]. At the same time, increasing the bandwidth of mobile data access to broadband levels can improve the effectiveness of public safety networking. Some private-public partnerships could help accelerate this; for example, Ricochet agreed to provide 1000 free modems to Denver city police cars as part of its application to reactivate its network locally after the bankruptcy of original parent Metricom [27].

Other examples of wireless public safety technology include, the development of a combined FM subcarrier/Wi-Fi enabled emergency medical services. This service makes use of FM subcarrier technology to deliver medical data, such as medical conditions and emergency contacts, to the ambulance. The ambulance then acts as a base station transmitting to paramedics up to a mile away.

As wireless services become more ubiquitous, it is likely that we will expect them to support a broad set of public safety communications. The scope of this coverage may vary depending upon the user, the provider, the type of service, and its cost. A basic emergency service ("911") may be among the first expected, but other lesser known services, such as priority access service and priority restoration, may soon follow.

## IV. CONCLUSION

Given the state of broadband adoption and the broadband policy debate, broadband wireless' opportunity to play a substantial role in adoption rests on providing viable competition to wireline without government subsidization. The FCC and Congress have correctly understood that spectrum policy reform enabling technology and business innovation is likely necessary for this to happen. Beyond competition policy, though, broadband wireless can advance other public interest policy goals, such as closing the digital divide, enhancing public safety, and democratization and diffusion of network control.

Broadband wireless entrepreneurs will have to overcome very low awareness of wireless as an option and be cognizant in particular of the relatively low value consumers place on ease of installation relative to other attributes and, more importantly, the relatively high value placed on reliability. Careful engineering of broadband wireless will be necessary to position reliability attractively relative to wireline alternatives.

Finally, broadband wireless can uniquely address mobile access. This not only provides a unique

market for wireless but also benefits all users of broadband by adding mobile users to each application's user population, promoting additional application development and economies of scale.

## REFERENCES


[1] M. Jackson et al., *Broadband Demand Study Final Report*, November 15, 2002. Online at http://itd.colorado.edu/broadband_demand.html. Last Accessed: January 21, 2003.

[2] *Current Population Survey: Computer and Internet Use Supplement*, Bureau of Labor Statistics, U S Government, September 2001, Online at http://www.bls.gov/cps/ Last Accessed: January 21, 2003.

[3] "High Speed Services for Internet Access: Status as of December 31, 2001," U. S. Federal Communications Commission, July 2002, Online at http://www.fcc.gov/Bureaus/Common_Carrier/Reports/FCC-State_Link/IAD/hspd0702.pdf Last Accessed: January 21, 2003.

[4] "Behind the High-Speed Slowdown," BusinessWeek Online, September 17, 2002. Online at http://www.businessweek.com/technology/content/sep2002/tc20020917_2824.htm. Last Accessed: January 21, 2003.

[5] M. Pastore, "Broadband Prices Are Up; Adoption Rates are Down," CyberAtlas. Online at http://cyberatlas.internet.com/markets/broadband/article/0,1323,10099_957511,00.html Last Accessed: January 21, 2003.

[6] "Building a Positive, Competitive Broadband Agenda," Positively Broadband. October, 2001. Online at http://www.positivelybroadband.org/library/whitepapers.shtm Last Accessed: January 21, 2003.

[7] "A National Imperative: Universal Access of Broadband by 2010." TechNet. Online at http://www.technet.org/news/newsreleases/2002-01-15.64.pdf. Last Accessed: January 21, 2003.

[8] M. Jackson et al., *International Implications for Broadband Policy*, January 15, 2002. Online at http://itd.colorado.edu/broadband_demand.html. Last Accessed: January 21, 2003.

[9] M. W. Smith and H-T Leung, "Finding the killer application – the role of the Broadband Applications Laboratory," *BT Technology Journal*, vol. 20, no. 1, January 2002, pp. 11-21.

[10] N. Victory. "Creation of a Broadband Universe: A 'Big Bang Theory'", Speech delivered at the Alliance for Public Technology Broadband Symposium, Washington, D.C., February 8, 2002.

[11] D. Hatfield et al., "Broadband Internet Access, Awareness, and Use: Analysis of United States Household Data," *Pacific Telecommunications Council Conference 2003*, Honolulu, Hawaii, January 19-23, 2003.

[12] B. Compaine, *The Digital Divide: Facing a Crisis or Creating a Myth*. Cambridge, MA: MIT Press, 2001.

[13] F. Bar, et al., Access and innovation policy for the third-generation Internet, *Telecommunications Policy* 24 (2000), 489-518.

[14] "Remarks of Michael K. Powell, Chairman, Federal Communications Commission," Speech at the Goldman Sachs Communicopia XI Conference, New York, NY, October 2, 2002. Available online at http://www.fcc.gov/commissioners/powell/mkp_speeches_2002.html. Last accessed January 21, 2003.

[15] A. Eftekhari, et al. "Feasibility of a Fixed Wireless Access Business," *International Symposium on Advanced Radio Technologies*, 4-7 March, 2003, Boulder, Colorado USA.

[16] *Spectrum Policy Task Force Report*, ET Docket No. 02-135, Federal Communications Commission, November 2002.

[17] R. Flickenger, *Building Wireless Community Networks*. Sebastopol, CA: O'Reily, 2001.

[18] D. O'Shea, "Peace, Love & Wi-Fi," *Telephony*, March 18, 2002.

[19] "Cable provider wages war against Wi-Fi freeloaders," *Telephony*, July 15, 2002.

[20] J. Markoff, "More Cities Set up Wireless Networks," *New York Times*, January 6, 2003.

[21] "Ad Hoc Peer-to-Peer Routing Technology," Online at http://www.meshnetworks.com/pages/technology/intro_technology.htm Last Accessed: January 21, 2003.

[22] *Jumpstart Broadband Act: Staff Working Draft*. Office of Senator George Allen, November 19, 2002.

[23] "Wi-Fi Access Already Turns Nasty," *Communications Today*, v. 8, i. 161, August 21, 2002.

[24] Parker, Closing the digital divide in rural America, *Telecommunications Policy* 24 (2000), 281-290.

[25] "Unwiring the Web," *Technology Review*, v104 i10, December 2001, pp. 22-23.

[26] "FEMA targets public-safety wireless stovepipes." *Government Computer News*, July 1, 2002, v.21, i.17, pp. 14-15.

[27] B. Koerner, "The New Old Thing," Slate, December 6, 2002. Online at www.slate.com. Last Accessed: January 21, 2003.