# Why Broadband Really Matters: Applications and Architectural Challenges

*Broadband is getting massive hype. What characterizes it, and what is it really good for?*

by **Clifford Lynch**

It's easy to caricature the broadband business and technical problem simply as how we get wires (or fibers or wireless services) that can support very fast network connectivity into all the homes, schools, businesses, and other places in this country. The public policy problems can be similarly oversimplified as how to disenfranchise the fewest people as broadband services roll out, and (maybe) how to equalize the expense to consumers of broadband connectivity, even though the costs will probably vary radically depending on factors such as population density ("universal service"). If someone asks why we need all this broadband service, the answer is usually a vague appeal to "interactive video" and related applications, often with a hint that it's a really stupid and somewhat tasteless question.

There's a lot more at stake in the transition to broadband than this, and I believe we need to think carefully about the issues here. We need to come to an understanding of what constitutes and characterizes broadband service, and why it matters. Why it matters will largely be driven by applications, and I believe the need to access applications is what will make (or break) the public policy case for universal service. It is also worth noting that many of the universal service arguments are made by analogy to electrification or access to telephone services, and I think they focus far too narrowly on bitways. If we are going to talk about meaningful universal service, we need to talk about what applications are going to be free or very inexpensively available through the broadband connections. This is a different issue from electricity or telephony, in part because it's a continuing service rather than merely an installation challenge.

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We need to be realistic about geographic burden for rural customers. They can be reached via satellite and we can make the business and economics of this work (either by engineering or by cross-subsidy), but we cannot repeal the speed-of-light propagation delay. Fiber to every farmhouse will be a long time coming. Many rural users are simply going to lose, at least in the near term, on very-high-bandwidth applications, especially low-latency ones.

I will sketch my perspectives of the characteristics of broadband service, and then consider the sorts of applications that connectivity service with these characteristics can enable. This article was occasioned as I tried to organize my own thinking about broadband when I was recently appointed to a National Research Council committee on last-mile broadband issues (see www.cstb.org), but in no way reflects the views of that committee. I welcome comments from readers on the issues presented here.

## Broadband Services

The obvious characteristic is that broadband is fast, and this factor has received the most attention. It is fast at least downstream (toward the user) but may be considerably slower upstream (from the user back out to the network) in some asymmetric configurations. This may either be a technical constraint or a pricing artifact. Although it would be

useful to discuss what "fast" really means, it's clear that the consumer expects the network and the last-mile connections to be fast enough to support the simultaneous transmission of individualized high-quality video to each user, with perhaps some reasonable level of video quality sent upstream by each user as well. These requirements seem to dominate everything else having to do with audio, still images, or data in most home, school, or small office settings. It is much less clear who expects to function as a server for this kind of content and to what extent this will be supported by basic broadband service and at basic broadband prices.

While most current consumer-oriented broadband offerings greatly improve activities such as Web surfing, it's much less clear that they can meet these expectations, at least in their current form.

There are a number of other characteristics of broadband connectivity; some are controversial and others are not. For example, there seems to be general agreement that a broadband connection is always on: It can continually be transmitting and/or receiving data independently of other activities that may be taking place at the user's site, such as telephone or television use. More controversial but really crucial, in my view, is that a broadband connection must link a user network to the Internet rather that just an individual machine (though at least initially connection of a single machine may be a popular and common degenerate case). As home machines and other information appliances and network-ready appliances proliferate and as network-attached sensors become inexpensive and commonplace, I believe the common case will be a broadband network connecting a home or office full of machines, appliances, and sensors to the Internet. This has extensive architectural implications.

There are other interesting technical characteristics that I have not heard much discussion about. For example, the ability to multicast to all broadband terminus points in a specific geographical area is enormously important for supporting certain kinds of applications. Technically this should not be overwhelmingly difficult to do, but it's not clear whether it's been engineered into current systems.

It is also unclear how managed quality of service interacts with expectations about broadband. Certainly people expect to be able to receive, and possibly transmit, good-quality video and audio. Whether this will be achieved primarily by overprovisioning or by managed quality of service (perhaps coupled with differential or demand pricing) is yet to be seen.

We need a frank discussion about reliability of network connections in relation to broadband. If broadband is simply a way to deliver pay-per-view video entertainment, reliability isn't very important. But if it becomes a lifeline to the network for consumers and small businesses, reliability is a serious factor. Current practices in addressing and route aggregation and advertisement by most Internet service providers make it essentially impossible for a home or small business concerned with reliability to use, for example, both a cable-based and digital subscriber line (DSL) connection simultaneously so that if one link fails, the consumer's network remains connected to the Internet. This kind of redundant connection is a common practice for large organizations that require highly reliable network access and are willing to pay for multiple network connections (from multiple providers) as a way of obtaining it. Today this level of reliability is limited to large networks operated by big businesses and universities.



## Broadband Service Applications

The three big applications that are being promoted for broadband, and that seem to have some serious investment behind them, are shopping, communication, and entertainment. Shopping would include the ability to browse blindingly fast through high-quality images of products, to view video clips demonstrating products, and to use new tools such as virtual clothing fitting and modeling applications. (Upload the parameters of your body and the system will show you what you'll look like in the clothing.) Communication is mainly audio and video conferencing—point-to-point and multipoint. I think it's debatable how much demand or readiness exists for video conferencing (particularly outside the shopping or entertainment contexts), and current telephony works reasonably well and reasonably affordably for the audio applications. Entertainment is potentially huge and involves replacing physical artifacts (videocassettes, DVDs, audio CDs, and books) with digital access, either on a download or pay-per-view model. Making this work on a large scale is more complicated than it sounds because it involves, for example, the integration of consumer electronics devices (TVs, audio players, etc.) with a home network and home computers. Not to mention the intellectual property and business model issues.

It's hard to be sufficiently cynical about the convergence of television and the Net into interactive entertainment services, particularly given the history of failed attempts to develop compelling content. Scott Rosenberg (see www.salon.com/tech/col/rose/2000/03/17/broadband) captures it perfectly: "But the purveyors of 'interactive entertainment' … [are] talking about the same ill-defined stuff that the developers of 'interactive TV' have been talking about for a decade: Chat live with other fans! Vote on how the plot line should move! Click on an actor's scarf to buy it!"


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To be sure, there's more to entertainment—and more novel prospects—than replacing currently popular physical goods or realizing mythical TV-Web convergence. Think about multiplayer interactive games, toys that can communicate with television and the network, or interaction with simulations. A whole group of new industries could bloom. There's a lot at stake with all these applications because the entertainment industries and their marketing channels to consumers are being restructured, revenue flows are changing, and problems regarding protection of intellectual property in disembodied digital forms are mounting.

It's difficult to use these three applications as justification for a large, expensive, and ambitious public policy goal of bringing broadband services to the majority of homes, schools, and small businesses in the United States. But there are actually a number of other important potential broadband applications—some of which depend more on characteristics of broadband services besides fast connectivity—that link closely to well-accepted public policy goals such as promoting public safety, health, and education. What's mentioned here are only a few examples; there are probably many more.

The network could be used for public safety applications such as notifying households or other locations of problems. Most physical phenomena travel much more slowly than packets moving through a network: A seismic sensor network coupled to the Internet could provide 30 seconds to two minutes warning of an earthquake, depending on where you are relative to the epicenter and the size of the quake. Warnings of tornadoes, floods, and industrial toxic emissions could be addressed to specific geographic clusters of always-on networks; gas lines and appliances could turn themselves off automatically, and residents could gain critical seconds of warning.

Considerable amounts of medical monitoring and testing could move out to the network: heart monitors for cardiac patients, smart toilets that include

chemical sensors, and in-home medical laboratories on a chip are just some examples. Some of this is done now via dial-up, but the possibilities offered by sensors connected to home networks that are in turn linked to the Internet are only beginning to be explored.

There is a large class of home safety, security and monitoring, and home management and automation applications that could be well supported by the geographically addressable, always-on broadband connections. Appliances can call for help; meters can provide readings back to the central office automatically.

Education is a compelling application, and here we face a growing bandwidth divide. People on university campuses (where fast Ethernet "to the pillow" connections in dormitories for residential students are now commonplace), in wired schools, or in large corporate offices have much better network access than is possible today from most homes. For universities, broadband to the home offers a way of closing the on-campus/off-campus gaps, a crucial step as colleges and universities move more toward digital instructional programs. For parents who want to homeschool their children or professionals who want access to continuing education offerings, broadband access to the home may make all the difference. (We do need to think about where the educational content is going to come from, who will provide it, and under what terms.)

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Broadband is important for commerce and for jobs. Effective telecommuting for many workers is going to require broadband connections. And today the small business that wants to establish a serious Web presence to offer digital content or transact commerce has few choices: It can order an enormously expensive set of leased lines or it can make arrangements with a hosting service. Inexpensive last-mile broadband can level the playing field for these organizations.

## A Few Observations on the Architecture

We really need a good definition of "open access." The current discussions about sharing lines or cable facilities (for example, the debate about the exclusive arrangements that @Home enjoys) capture only a small part of the question—perhaps the least important part. There is a large and complex infrastructure of caching, bandwidth management, addressing, and related mechanisms that is needed to make broadband access work. Access and capacity constraints are being introduced in subtle and important ways. We need to talk about how open access interacts with these functions. Jerry Saltzer of MIT has written a wonderful brief paper (web.mit.edu/Saltzer/www/publications/openaccess.html) that offers an overview of these issues.

Connecting home networks instead of individual home computers is critical. The restrictions on multiple Net connectivity for small networks in today's Internet is a significant problem, but the large-scale deployment of broadband links to homes and small businesses will push it to the breaking point.

Privacy and security also are important issues. One hears cautionary tales about people who suddenly realize that cable is really a broadcast medium and that they can "see" machines on the network belonging to their neighbors that clearly do not expect to be seen. Most corporate Internet users have already introduced firewalls as good business practice (though they don't necessarily configure them intelligently or understand their limitations); will home users need to do likewise? What should the broadband provider do, and what is the responsibility of the consumer? How do we educate the consumer about these responsibilities? I believe broadband connectivity exposes the average, uninformed consumer or small business to extensive new risks.

Finally, in the architectural discussions, much of the focus is on single-family dwellings of rural and suburban America. Many people live in urban settings in large apartment complexes; many businesses rent space in large commercial office buildings. Many of these buildings already have complicated telecommunications facilities just to distribute telephony and cable. Landlords and broadband service providers are making deals. I'd like to see some serious discussion about the problems in providing broadband access to a 900-unit, 30-story apartment building versus an individual home, and the implications for the open-access debate.

## Broadband Matters for More than Entertainment

Broadband does matter, and for a lot more than ushering in the next phase of consumer nirvana or enabling dubious interactive television/network convergence. It creates opportunities for a spectrum of novel applications ranging from new forms of entertainment and education to ways of improving health and safety. And in particular, it matters very much for education, where a new digital divide threatens to open between residential and commuter students and between distance learners and those who can come to the campuses if we do not see broadband access widely and affordably deployed. *e*

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