Whither Broadband Policy?

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There is no commonly agreed definition of broadband and the various proposals reflect different visions as to the nature of a future broadband environment. A range of platforms with different technical and economic features are available. This heterogeneity will have to be considered when assessing and designing public policies. It is important also to recognize that broadband is a shared infrastructure technology. The treatment of joint and common costs raises many complicated issues and may determine the success or failure of policies. Public policy responses will further have to be tailored to the spatial and product characteristics of broadband services. In the case of predominantly private or club goods, the role of the public sector will best be focused on measures facilitating demand synchronization and aggregation. Where the mix of benefits of broadband services has strong public good characteristics other means might be more effective, including public funding or even direct provision by a government agency.

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1. Introduction

Broadband access to the internet facilitates a wide range of services and applications that are difficult to configure or inconvenient to use in a narrowband environment. There is no commonly agreed definition of broadband and the various proposals reflect different visions as to the nature of a future broadband environment. A range of platforms with different technical and economic features is available. In assessing and designing broadband policies, this heterogeneity must be kept in mind. Broadband presents a range of service and cost options and an optimal choice of advanced technologies must carefully consider such trade-offs. It is important also to recognize that broadband is a shared infrastructure technology. Such technologies usually are characterized by a high share of joint and common costs. As stakeholders may benefit differentially from investments in advanced capabilities the allocation of common costs of infrastructure upgrades raises many complicated and contested issues and may determine whether or not desirable investment in broadband is forthcoming.

Recent U.S. data presented by Pepper (2002) shows that broadband service is widely available. At the beginning of 2002, the two dominant technologies for broadband access were cable modems and DSL. Cable modem service with a speed of >500 kbps is available to approximately two thirds of U.S. households. DSL service with a speed of >350 kbps is available to approximately half of U.S. households. More than 80% of U.S. households have access to either cable modem or DSL service. Nearly all U.S. households are in the footprint of satellite broadband service and terrestrial wireless internet access, in particular via 802.11 hotspots is available in an increasing number of locations. The number of subscribers is growing slower than the availability of service. Cable modems were first introduced in 1995 and DSL, with some delay, in 1997. However, the number of subscriber did not pick up until 1998 and 1999 respectively. By March 2002, the number of subscribers had increased at a relatively steady pace to about 13% of all households. Slightly less than two thirds of all broadband subscribers relied on cable modems and slightly more than one third on various forms of DSL. The diffusion rate of broadband service during these first few years was higher than that of color television, VCRs, mobile phones, or CD players. However, it was slightly below the initial diffusion rate of PCs and significantly below that of black and white television.

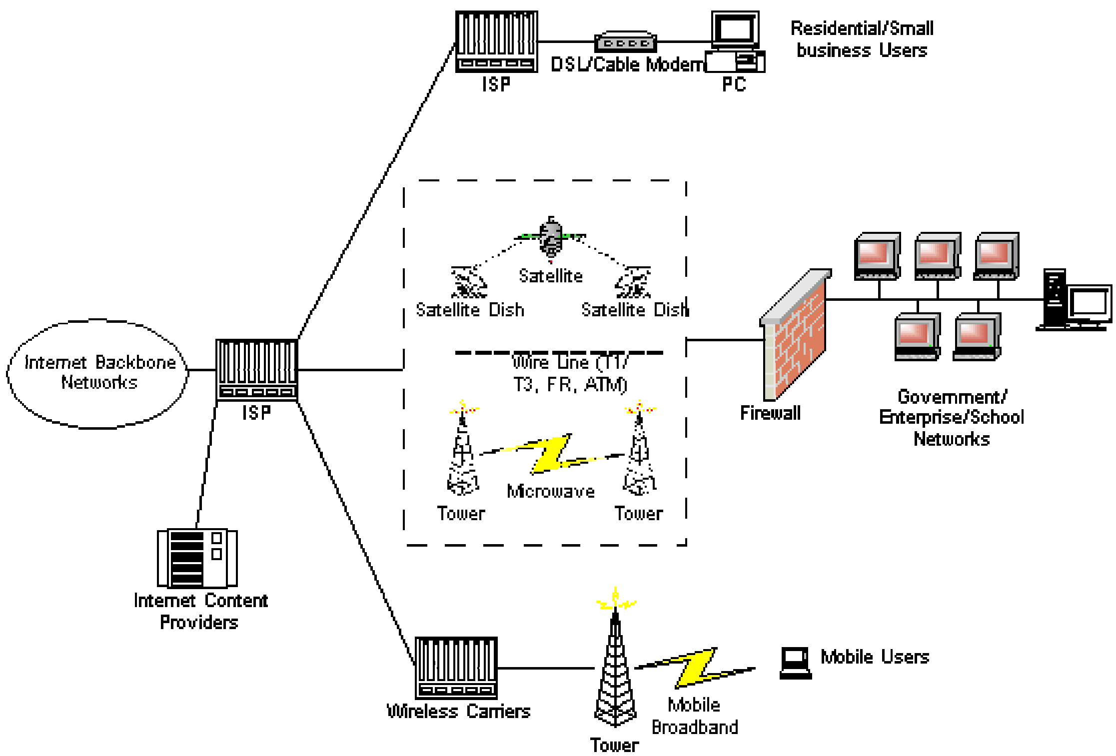
Despite this steady expansion there seems to be concern that the diffusion of broadband is “too slow” and the sentiment is widespread that public policy should promote broadband investment and applications. In the U.S. the federal government and all 50 state governments have adopted initiatives in support of a more rapid adoption of broadband services. Other industrialized nations also search for frameworks for broadband policy although there is a wide range of views as to what the most effective policy framework should look like. Policy experiments range from laissez-faire approaches intended to free entrepreneurs from regulations detrimental to broadband investment to direct government ownership and operation of networks. Given the relatively high degree of uncertainty surrounding broadband, such diversity may be desirable as it can promote the generation of social knowledge as to what models work and which ones do not. Nevertheless, a more thorough conceptual understanding of the role of public policy should help elevate the debate. The comparison with earlier communications technologies may be misleading. While they were specialized technologies, broadband is a shared platform. This may lead to very different policy implications.

This paper is a first step towards such a more comprehensive and integrated framework. One of the goals of the paper is to analyze the bandwidth requirements of different types of service and thus highlight the choice options of broadband policy. Moreover, it attempts to explore the implications of these trade-offs for the promotion of broadband diffusion. Section two of the paper provides a brief review of the technology and economics of broadband. The third section provides a review of current research on the claimed benefits of broadband networks and services. It also explores the nature and geographic scope of the claimed benefits. Section four is dedicated to a review of current initiatives and rationales of broadband policy. Building on this discussion, we explore the conditions under which market forces will be insufficient for broadband deployment in the fifth section.

2. Broadband technology and economics

Broadband refers to a set of general-purpose electronic communications technologies rather than one specific technological solution. Common features include significantly higher bandwidth than dial-up networks, the reliance on some form of packet switching, and "always on" functionality. Broadband networks are also superior to traditional networks in terms of latency (the time it takes to deliver a packet across the network) and jitter (the variance in latency). There is no commonly agreed definition as to what bandwidth constitutes "broadband". The U.S. Federal Communications Commission (FCC) as well as the Canadian Broadband Task Forces chose a bandwidth of 200 kbps for downstream transmission as the cutoff point for broadband service although this is not a rigid number and may shift upwards with changes in technology and uses (OECD 2002). The International Telecommunication Union (ITU) considers a transmission speed of 1.5 to 2 Mbps as broadband. The Computer Science and Telecommunications Board (CSTB) of the National Research Council (NRC) proposed a flexible definition capturing the dynamic evolution of broadband. The two-part approach defines broadband as transmission capacity in the local access link that is sufficient to not constrain a user's ability to run advanced applications. Moreover, broadband should provide sufficient performance and wide penetration of services to encourage the development of new services and applications (NRC 2002).

Figure 1
Basic broadband network architecture



Some broadband access platforms are evolutions of existing networks whereas others require fully new networks (see Figure 1). The different types of Digital Subscriber Line (DSL), cable modems, or powerline communications are upgrades of already existing network infrastructures. Fixed wireless access (FWA) technology and broadband wireless solutions require at least some unique network investment. For example, IMT 2000 or 3G wireless services can only be offered after the installation of a new radio access network. The investment costs of these different solutions varies widely as does the scalability of the network. For example, DSL or cable modem service require a smaller sunk investment expense than satellite based service and can be adjusted more easily to varying demand. Broadband access technologies therefore offer a range of cost-functionality combinations. The technological and cost characteristics are more similar at higher levels of the network – the middle mile and backbone networks – which typically use similar topologies and protocols. Table 1 provides a summary overview of the spectrum of broadband access technologies and some of their key features.

Table 1
Features of broadband technologies

Types	Sub-types	Characteristics & features
DSL (Digital Subscriber Line) -Always on -Use local loop line for individual customers no share with other users (Stable connection)	ADSL (Asymmetric DSL)	-Asymmetric because of its focus on downstream direction sending data to the end users -Most common form of DSL for residential and small business users -Range from 1.5 to 6.1 Mbps in transmission speed
	G. Lite	-Slower ADSL that does not use line-splitting at the end users, but filters traffic at the telephone company's facilities -Up to 1.5 Mbps for downstream -From 32 Kbps to 512 Kbps for upstream
	HDSL (High DSL)	-Used within a corporate, between telephone companies and users -Symmetrical bandwidth (equal amount of traffic available in both upstream and downstream) -Up to 2.3 Mbps in transmission speed
	IDSL (ISDN DSL)	-Closer to ISDN, not broadband technology -Symmetrical
	RADSL (Rate-Adaptive DSL)	-A kind of ADSL technology that adjusts the access speed based on the condition of the line
	SDSL (Symmetric DSL)	-The same technology as HDSL with a single line -From 1.5Mbps to 2Mbps in transmission speed of each direction
	VDSL (Very High DSL)	-Higher data rates with a limited range -From 51 to 55Mbps in transmission speed
Cable Modem		-Always on service -Simultaneous access to both the Internet and cable TV -Two-way connection with speed from 1Mbps to 10Mbps -Slower speed in transmission if many users connect and transmit data at once

Fiber Optic Cable		-High speed in transmission up to 10Gbps -High cost to implement
FWA (Fixed Wireless Access)		-Ideal bridge for the gap between the backbone and the end users without bottlenecks -High cost -Shared between users (declined speed when there are many access from users)
Satellite		-Effective for reducing the gap between urban and rural areas -High investment cost -Possible to be disrupted in bad weather condition
Mobile wireless		-IMT 2000 or 3G mobile -Up to 2Mbps data transmission
Power lines		-Electrical power networks -1-2Mbps in transmission speed

Broadband technologies are general purpose, shared networks. Sharing takes place at the level of individual users, as the network is used for multiple purposes such as voice, e-mail, online games, or streaming services. At higher levels of the network sharing also takes place between different users. Compared to a circuit-switched voice network, sharing starts at nodes "closer" to the end user. Given the high capacity of the network, the overall cost structure consists of a relatively high level of fixed and low incremental costs. Moreover, a high percentage of the overall costs of broadband networks is joint and common to a multitude of services. This raises complex issues with respect to the apportionment of the shared costs. In the presence of economies of scope, the sharing rules and conventions will also have a direct impact on whether or not an efficient cost-minimizing network architecture will emerge. Moreover, the extent of economies of scope will also influence the emerging market structure for the provision of broadband access services (Faulhaber and Hogendorn 2000).

3. Benefits of broadband

The public policy debate overflows with claims as to the benefits of broadband networks and services although very few numerical estimates of expected benefits are available. Potential benefits of broadband are best measured relative to the status quo ante of electronic communications networks. One possible approximation of the benefits of broadband is the change in social surplus (consumer plus producer surplus) from the introduction of broadband technology platforms. Such benefits can originate from various sources. In as far as broadband networks allow the provision of existing services at lower costs, broadband will increase social surplus under given demand conditions. Compared with narrowband – dial-up or wireless – internet access broadband platforms also extend the set of feasible services and applications. In other words, they shift the production possibility frontier of an economy outwards. As new consumption opportunities are generated, social surplus is again enhanced.

Crandall and Jackson (2001) is the only paper that uses an estimate of consumer and producer surplus in assessing broadband. As some of the benefits of broadband will only materialize after some maturation process, Crandall and Jackson base their analysis on a long-term perspective. The authors evaluate the benefits of broadband using two alternative approaches. The first approach uses a conjectured demand curve for broadband service assuming a monthly subscription charge of $40. The second approach examines specific applications and estimates the benefits accruing to consumers. Both approaches calculate benefits under two scenarios, a low estimate based on the assumption of 50% broadband penetration and a high estimate based on full diffusion of broadband, equivalent to the current penetration rate of voice telephone service. Based on the service specific approach, total annual benefits from all forms of broadband range from $272 billion in the partial diffusion to $520 billion in the universal diffusion scenario. Similar results, ranging from $297 billion to $460 billion annually are obtained from the conjectured demand function model.

Despite the advantages of a clearly defined concept of benefits, the vast literature on broadband typically does not use such a stringent, operational notion. Nevertheless, strong cases are made in favor of policies facilitating the more rapid diffusion of broadband platforms. For example, in its report on electronic commerce the OECD (2000) concludes that the lead of the U.S. in this area is related to the wider availability of flat rate and always on internet access. Realizing the overall economic benefits from e-commerce would thus require policies facilitating always on access. In one of the most comprehensive analyses of broadband issues, the Computer Science and Telecommunications Board (CSTB) of the National Research Council (NRC) identified a wide range of benefits of broadband. Nevertheless, if came to the conclusion that the factors influencing broadband deployment are highly complex. The resulting uncertainty with regard to the pace of broadband diffusion at best requires cautionary steps, including an assessment of the effectiveness of policy options, and policy designs that reduce the risk of unintended and undesirable consequences. These include "demand stimulation and aggregation, grant and loan programs, and municipal initiatives fostering market entry and competition" (CSTB, 2002, 206).

Many more claims as to the beneficial effects of broadband are made in the context of specific applications. A survey of the pertinent policy documents and research literature reveals that most of the potential benefits are expected in six categories of applications (Bauer, Gai, Kim, Muth and Wildman 2002):

- Telemedicine
- E-learning
- E-business
- E-government
- Telecommuting
- Media and entertainment

A closer scrutiny of the claimed benefits reveals that not all require high bandwidth platforms. Rather, in every category important choices exist and certain goals can be reached with different technological solutions. This point shall be illustrated for the first four areas (for a more detailed discussion of telecommuting and media & entertainment see Bauer, Gai, Kim, Muth and Wildman 2002).

In the field of telemedicine, which is the provision of health care services, clinical information or medical education using telecommunications technology (Maheu et. al. 2001, Canadian National Broadband Task Force 2001), synchronous and asynchronous services need to be distinguished. Bandwidth requirements vary widely with the service provided and not all applications demand broadband. Clinical applications include telediagnosis, telemonitoring, teleconsultation, teleradiology, the use of remote medical instruments, and behavioral healthcare mediated through telecommunications. In addition to clinical applications, information and communications technology can reduce the administrative costs of health care providers and facilitate continuing education programs. Health care professionals distinguish between different levels of telemedicine, requiring different network support. Table 2 illustrates the different telecommunications needs of selected applications. It is clear that only more advanced applications require broadband platforms. This threshold may shift upward with more sophisticated compression techniques.

Table 2
Forms of telemedicine and their bandwidth requirements

Applications	Minimum Network Requirement	Supplementary Devices / Resources
Telediagnosis	POTS	-Telephone, mail, email or fax
Teledermatology	POTS	-Telephone, mail, email or fax, video display units with high resolution image data if necessary
Teleultrasound (Telesonography)	-4 or 6 ISDN lines for cardiology real-time motion video (256 or 384Kbps)	1. Experts with extensive information regarding the overall state of the patient, moderate operator, and an expert for reading images at once 2. Devices, PACS, MM tools, video display units, audio & video codecs, VC conference management tools, electronic board, microphones, speakers, ultrasound device, remote control, control board
Telemonitoring	-56K, BRI ISDN, fractional T-1 -ATM, DSL in case real-time multimedia communication is needed	1.An expert who monitors the sent biosignals and image data 2. Devices: blood pressure monitors, pulmonary function monitors, electronic stethoscope, tele-EKG (Electrocardiogram), tele-echocardiography and ultrasound systems, untegrated light, video camera platforms, dermascope, 1-CCD camera, dental cameras
Teleconsultation	-At least fractional T-1 -ATM, DSL or cable network	1.High resolution visual data and video display units for patient monitoring 2. Videoconferencing systems and interactive video room systems 3. Computer-supported teleconferencing systems
Teleradiology	-ATM	-PACS (Picture Archiving and Communication Systems), high-resolution monitors, connectivity system, frame grabbers, compression techniques for heavy loaded image or video data, store-and-forward systems (audio and video capture card, camera, microphone, and image management software)

E-learning also can be configured in various ways. Asynchronous e-learning uses web-based learning modules but does not support real time interaction between the instructor and the students. Synchronous e-learning consists of on-line real-time lectures, which typically have to be joined by students at the time of their delivery. Additional asynchronous functions typically support the learning environment. Most demanding in terms of bandwidth are forms of collaborative e-learning in which students have to interact continuously to solve problems or engage in other learning activities. Table 3 illustrates that only certain forms of e-learning require broadband support.

Table 3
Broadband requirements of e-learning

	Applications	Network Demands	Complementary Functions & Tools
Asynchro-nous	Computer-Based Training Modules (CBT), Multimedia Database Support System (MDS)	POTS, ISDN	Email, automatic upload of educational materials
Synchronous	Remote Lecture Room (RLR), Interactive Home Learning (IHL)	Up to 6 ISDN channels, ATM, Internet protocol stack	Bulletin board, videoconference or audio conference systems , email, chat room, file exchange tool
Collaborative	Remote Interactive Seminars (RIS)	Up to 6 ISDN channels, ATM, Internet protocol stack	Bulletin board, videoconference or audio conference systems , email, chat room, file exchange tool

E-business refers to the integration of information and communications technology into every stage of the value chain and thus is a much broader concept than e-commerce. It includes the use of advanced ICT to attract and retain customers, to streamline firm operations such as supply chain or inventory management, to automate business processes, and to collect, analyze and share business intelligence about customers and company operations with employees, suppliers, and business partners. There is widespread agreement that, with few exceptions, broadband is a prerequisite for the successful diffusion of e-business services. Although no concrete estimates of the overall benefits of e-business solutions are available, it is commonly expected that they include reduced transaction costs, increase operational efficiency, and facilitate new ways of customer-supplier interaction (as in the case of m-commerce). However, e-business solutions also entail possible risks and costs for communities as local business revenues may be siphoned off by distant businesses.

Table 4
E-government applications and bandwidth requirements

e-Government Applications	Technology	Network Implications	Bandwidth requirement
General information publication, search and retrieve	Web browsing, file downloading and uploading (HTML, HTTP, FTP, Telnet, database, etc.)	Fast web page downloading and file transferring	-Low bandwidth requirement for individual users -High bandwidth and capacity requirement for government networks
G2C transactions (ticket payment, bill payment, tax payment, permit application, filling of licenses, online crime reporting, online Citizens complaint, Street light repair request, online voting	Web browsing, Web interactions (HTML, HTTP, FTP, Telnet, Java, database etc.)	-Fast web page downloading and file transferring -Instant response required by real-time interactivity -Security and privacy	-Low bandwidth requirement for individual users -High bandwidth and capacity requirement for government networks
Multimedia Applications (Webcasting, 3D navigation, high definition pictures and video, IP telephony)	Streaming media, VRML, HTTP, etc.	-Fast data transmission to ensure video and audio quality, interactivity -Low latency and jitter	High bandwidth connections are required or strongly recommended
G2B transactions (Government e-Procurement, G&B collaboration)	EDI (Electronic Data Interchange), Integrated voice, data, and video transmission	-7 days/week, 24 hours/day availability -Time-critical interaction and response -Security	High bandwidth requirement; broadband is an enabling factor
G2G (inter-government information sharing and transactions, video conferencing) and Internal efficiency and efficacy (Intra-government information publication and sharing, internal daily operations)	Integrated voice, data, and video transmission	-7 days/week, 24 hours/day availability -Time-critical response -Security -Flexibility	High bandwidth requirement; broadband is an enabling factor

E-government is another application that is often portrayed as dependent on the availability of broadband infrastructure. E-government includes the use of automated systems in transactions between the government and the public as well as the exchange of information between governments. Local, state and the federal government have started to use the internet to better communicate with citizens. Applications include the use of websites to make information available to the public, the utilization of the internet to make forms and applications available, and the use of the internet for transactions (e.g., drivers license applications, payment of tickets, or the filing of taxes). In addition, some agencies have begun to use videoconferencing to conduct proceedings with remote stakeholders and there are discussions to establish tele-courts. Table 4 summarizes the technological requirements for different kinds of applications. As in the other areas it is clear that not all e-government applications require broadband.

This analysis provides an important basis for the discussion of public policy issues. It is a first indication that it is probably necessary to adopt a differentiated view of broadband networks. The best networking solution is very likely dependent on local conditions and the overall visions of a community. These issues are further explored in the next section.

4. Status quo of broadband policy

Governments worldwide have adopted measures to support the rapid diffusion of broadband. With few exceptions such as Firth and Longstaff (2002) no serious challenge to the basic premise that broadband is desirable has been raised. There is widespread agreement that policy should encourage broadband deployment and reduce digital divides. The vast majority of the policy debate centers on the appropriate means to realize the potential benefits from broadband. Given the increased belief in market forces and competition, there is a clear bias to use competition as the main driving force and the role of the government is envisioned as organizing the market. Important roles are the establishment of a clear and conducive regulatory framework and perhaps measures to increase the awareness of the benefits of broadband. Not surprisingly, proposals in favor of more or less government seem often shaped by the particular ideological stance of a stakeholder. This section first reviews some of the pending policy initiatives. The next section develops an analytical framework as a broader context for this discussion.

Proponents of less government involvement support their view with five arguments. First, since broadband systems are in the early stage of deployment and development the government lacks sufficient information to design appropriate policy measures. Therefore, governments should wait until it is clear which services private investors will not provide and why. Second, for similar reasons it might be too soon for governments to define areas that are not commercially viable and thus need financial support. Third, the very initiatives that governments can adopt to boost competition can distort broadband markets. Such distortions can change the shape of competition in broadband markets and may even slow the development of the private sector's competitiveness. Fourth, governments' support for certain broadband providers or municipal networks might cause local monopolies and have a negative impact on local industry innovation and efficiency. Last, where governments intend to provide financial support to public or private institutions, such as schools, libraries or hospitals, to help them build up broadband connections, it might be hard to evaluate and justify the government support without reliable criteria for the investments (OECD 2002).

Table 5
Overview of federal, state and local broadband policy measures

	Federal	State	Local
Information	Centers of excellence		
Communications	Centers of excellence		
Indirect financial support	Support for R&D E-rate program	Tax credits (MI) Low interest loans (MI)	Link Michigan Community networks
Direct government ownership		Multi-Use Network (Colorado)	Ashland, Oregon

Proponents of more active government involvement emphasize, first, that market forces will be insufficient to bring advanced broadband services to certain rural or poor communities with limited profitability (APT 2002). Second, in a broadband environment, content providers may be dependent on downstream network service providers and government intervention may be needed to assure sufficiently open network access conditions. Direct government ownership is one alternative to create an open access network infrastructure. Third, government investment or subsidies can speed up the upgrade of a regional network where it might take several years to attract private broadband providers. Last, governments are believed to be responsible for acting in the public interest when there are no concrete consumer demands in the broadband market during its early stage of growth (OECD 2002).

Governments can become involved as owners and operators of broadband infrastructure, as is the case in several U.S. states (e.g., Maryland, Iowa) and at the community level. More often, the government designs measures to support private sector investment and use. Direct supply-side measures include direct procurement programs, tax incentives, subsidies and grants, or the formation of public-private partnerships as is the case in many community network projects. More indirect supply-side measures include general tax incentives for research and development in ICT. Government measures can also affect the demand side, for example, in the form of the U.S. federal E-rate program intended to assist schools and libraries to get access to fast internet connections.

Table 6
Selected local broadband initiatives

	Objectives	Technology	Organization and financing
Electronic Villages, Virginia	Expansion of internet access outside of local university with broad synergies for political and economic life	Mix of Ethernet, fiber optical net, and mobile communications	Initially funded by communities and Virginia Tech, since 1995 private investors
Yolo Area Regional Network (YARN), California	Gateway to all local activities, including local politics, e-government, economy and education	Mix, final users predominantly DSL, some ISDN and	Privately owned, lower costs through demand aggregation
Eagle Mountain, Utah	Internet access for private and business users	Wireless communications	Privately owned and operated
Ashland, Oregon	Broadband internet access, cable television	Hybrid fiber co-ax network	Owned and operated by municipality
Prairie iNet (Iowa, Illinois, Kansas)	Broadband internet access	Wireless service in unlicensed 2.4 GHz band	Privately owned and operated
Multi-Use Network Project (MNT),	Access to efficient telecommunications	Mix of several fixed technologies	Public-private partnership between

Colorado	services for rural communities and small and medium-size enterprises		State of Colorado and Qwest
Totally Web Government Program (TWG)	eGovernment	Mix of fixed technologies	National League of Cities, IBM, National Association of Counties

In the U.S., most states and many communities pursue specific programs to facilitate the diffusion of broadband services (see table 7 for examples). One recent example at the state level is the Michigan Hi-Speed Internet Plan, enacted by the Michigan legislature in March 2002. This law established the Michigan Broadband Authority (MBA) as a non-profit organization to provide low-interest loans to communities and businesses in support of broadband networks. Another Michigan initiative is the Link Michigan program, which awards planning grants to groups of communities to explore options for higher speed network access. Moreover, a large number of communities have experimented since the 1980s with community networks. The experience with these networks is mixed, with some very successful projects and others that failed. For a list of selected projects and hyperlinks to them see LinkMichgan, Regional Telecommunications Planning Program, Resource Book, available at <http://lm.michigan.org/commnetprojres.html>.

5. Towards a generalized framework

From an analytical perspective it is necessary to explore whether decentralized decision-making by individual firms and potential users of broadband is capable of realizing a socially optimal outcome. In the light of our discussion of the differentiated network requirements of envisioned broadband services it seems helpful to further examine the nature of the benefits from broadband service as well as their spatial characteristics. Such an analysis reveals that the potential benefits from broadband service indeed have very different characteristics. Some benefits, such as more efficient procurement or reduced costs for certain health care services, are essentially private goods that can be fully internalized by the users. Other benefits, such as high speed access and support services in a business park may have the character of club goods. That is, they benefit a group of stakeholders and will only be supplied if that group acts collectively. If broadband benefits are such club goods, they will only be forthcoming if the "club" is formed. However, if the required "club" is established, all benefits are internal to its members. Finally, benefits may be pure public goods, accruing to a community or several communities at large. For example, the availability of advanced distance education technology may reduce the crime rate in a community and enhance the quality of life even for those who do not use distance education. In this latter case, the immediate users of broadband services cannot easily internalize the benefits and public policy action may be necessary.

Table 7
Spatial nature of broadband costs and benefits

		Benefits		
		Local	Inter-local	Global
Costs	Local	E-government	Tele-education	Tele-education
	Inter-local		Tele-medicine	Tele-medicine
	Global			E-business

In order to design appropriate policy intervention a better understanding of the spatial structure of costs and benefits from broadband networks is also necessary. Costs and benefits can be local in scope, they can be inter-regional or they can be global. This yields a total of nine possible scenarios, which are synthesized in table 7. If both the costs and benefits of broadband are local, policy decisions are best taken at the local level. If benefits and costs are inter-local or global, unique problems arise, as optimal policy will require coordination among the stakeholders in different communities. As long as the transaction costs of achieving such coordination are lower than the net benefits of broadband to all stakeholders, such an approach will likely be forthcoming. However, if coordination is complex and its transaction cost above the net benefits of broadband, voluntary coordination may not result in broadband investment. In such cases, coordination at a higher level of the political system may provide a solution. Additional problems arise in asymmetric cases, for example, when the costs of broadband are local but the benefits inter-regional or global. In the absence of transaction costs, optimal outcomes could be achieved regardless. However, under real world conditions the level of broadband investment will be shaped by the ability of the stakeholders to internalize effects through negotiation and coordination. Again, policy-making at a higher level in the political hierarchy may offer a feasible solution.

The shared nature of broadband networks may further complicate the effectiveness of market coordination. In order to make an investment into broadband infrastructure profitable, a minimum amount of demand may be required. If potential users' demand is articulated at different points in time, private investors may not find a project worthwhile. Thus, an important function of policy-makers could be the synchronization and aggregation of otherwise fragmented demand. In addition decentralized decisions may suffer from free rider behavior if additional users can be served at very low incremental costs once the network infrastructure is installed. In all these cases, some active government policy may be the superior strategy. Last but not least a comprehensive broadband policy needs to take the effects of infrastructure decision on content industries into account. There is conflicting evidence as to whether more open or more closed network environments stimulate vertically related industries more. However, a detailed exploration of these arguments is beyond the scope of this paper.

The preceding analysis delineates the conditions under which market forces will be insufficient for broadband deployment. Public policy responses will have to be tailored to the spatial and product characteristics of broadband services. In the case of predominantly private benefits or club goods, the role of the public sector will best be focused on measures facilitating demand synchronization and aggregation. Where the mix of benefits has the character of public goods other means might be more effective, including public funding or even direct provision. The majority of present broadband policy measures are not based on a systematic consideration of these issues. However, many of the practical policy measures explicitly or tacitly recognize at least some of the dimensions of the problem. For example, the LinkMichigan program encourages communities to plan broadband networks jointly. Such an approach may be justified if the costs and benefits of broadband reach beyond local communities.

5. Conclusions

The paper provides a review of current research on the claimed benefits of broadband networks and services. Recurring benefits of broadband are identified in education, health care, business infrastructure, government, and civic life. Our survey reveals that the potential benefits of broadband depend on a multitude of demand and supply as well as location factors. Therefore, in those cases where specific policy intervention may be required, it will have to be designed in a multi-tier fashion, reflecting the national, regional and local dimensions of broadband networks and services.

We explore the nature and geographic scope of the claimed benefits of broadband in more detail. We find that some effects of broadband are private goods, some can be characterized as club goods, and yet others are public goods. From a spatial perspective, effects can materialize locally, regionally and nationally. We also find situations in which improved broadband access may cause local costs, for example, through a net shift of local business revenues to distant suppliers and locations. In situations where the effects of broadband reach beyond a local market, communities will inevitably be affected by the strategies adopted in other places.

Based on this differentiated analysis, we review the conditions under which decentralized market decisions will lead to optimal decisions for broadband deployment. Public policy responses will have to be tailored to the spatial and product characteristics of broadband services. In the case of predominantly private benefits (private goods, club goods), the role of the public sector will best be focused on measures facilitating demand synchronization and aggregation. Where the mix of benefits of broadband services is slanted towards club goods or public goods other means might be more effective, including public funding or even direct provision. Evaluating the existing policy portfolio against our conceptual framework for optimal policy design we find encouraging examples of broadband policy but also a need for more thorough analysis and reconciliation of policy measures with the structure of the policy problems.

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