BROADBAND INTELLIGENCE SERIES

BROADBAND 2020:
Achieving Ubiquity

Broadband
Center of Excellence
Resources for a Broadband World

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Advancing the broadband vision

"Affordable broadband connectivity, services and applications are essential to modern society, offering widely recognized social and economic benefits."

— United Nations Broadband Commission, Sept. 2013

Broadband networks, services and applications have become critical components of economic and social infrastructure, enabling new possibilities in the way individuals and organizations interact in areas of commerce, governance and personal services. A consensus has emerged across the globe that broadband — the receipt and delivery of information over the Internet at high speeds — is an essential tool for accomplishing tasks that contribute positively to economic activity and social welfare. In this context, affordable broadband access has come to be viewed as nothing short of a 21st Century human right. The U.S. academic and writer Susan Crawford calls high-speed Internet access "the two-way, general purpose communication on which the country's economic, cultural, political and social life depends."[i] The United Nations Broadband Commission asserted in a September 2013 report that "Affordable broadband connectivity, services and applications are essential to modern society, offering widely recognized social and economic benefits."[ii]

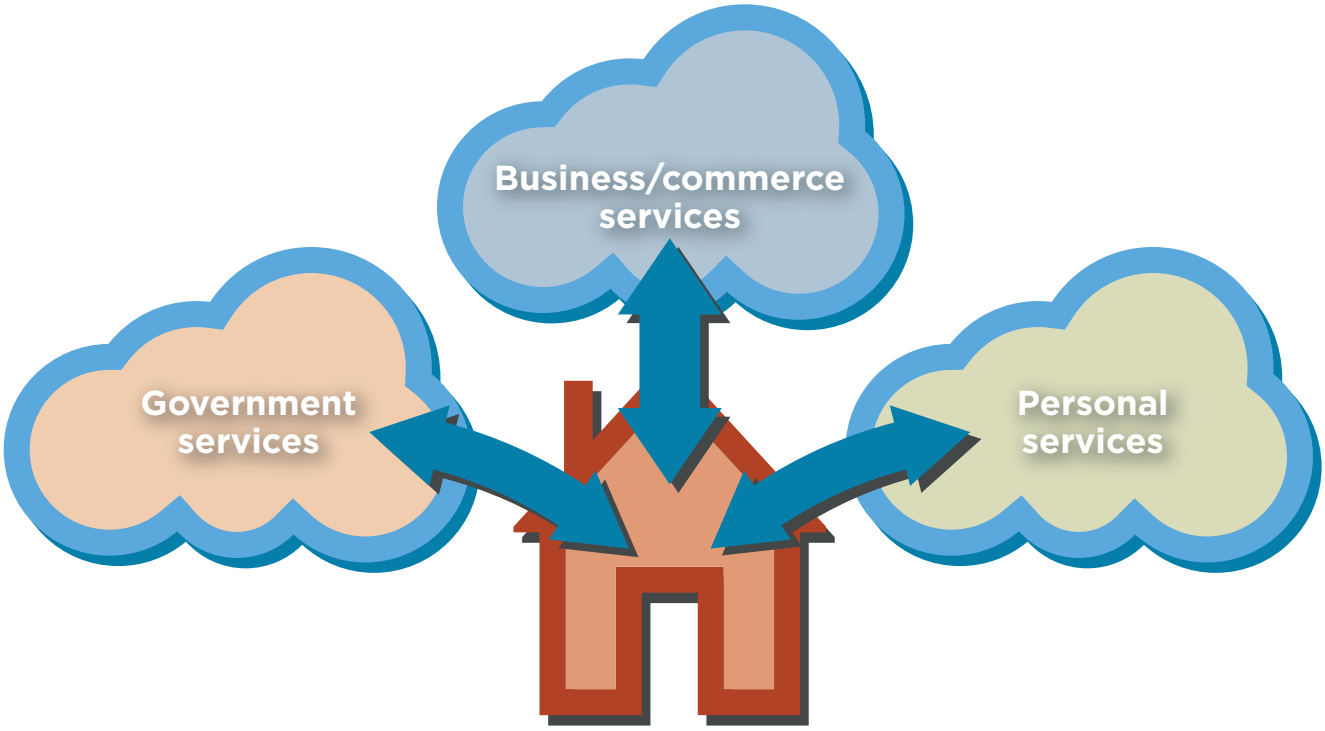
A full realization of these benefits, however, depends on overcoming obstacles that threaten to limit broadband's impact and benefit. These obstacles occur in seven critical areas:

- **Availability —** What percentage of people, residences and businesses have access to a broadband service in a given area?
- **Adoption —** What percentage of these potential users are actually connected to an available broadband service?
- **Affordability —** In a given area of coverage, how comfortably can an individual or family with average income pay for available broadband services?
- **Performance —** What is the bandwidth (bit rate), of the broadband service to and from the end user?
- **Utilization —** Of the available bandwidth what percentage actually is utilized?
- **Ease of use —** How easy and/or intuitive is it to make use of broadband connectivity and applications?
- **Services —** What applications are available that may compel usage and drive improve network performance?

The need to solve the above obstacles is apparent when considering the breadth of impact broadband may have.

Similar to electrical networks a century ago, broadband is a vital enabler of technology innovation. From entertainment, communication, social relationships and emergency response to healthcare, energy management, business, and family interaction, broadband — coupled with software that takes advantage of broadband's capabilities — provides an essential platform for a connected society. Broadband is the enabling agent that unleashes the power of the Internet by supporting a wide range of services and applications that were not possible with slower-performing IP networks.

A full realization of broadband's potential can produce ready and convenient access to a vast array of government, business and personal services of use to billions of people, accelerating the movement to a transformative, information-based economy.



Because of broadband's recognized potential, there is widespread interest in advancing wider adoption and usage while enhancing the range of services available via broadband. Reflecting this interest, the governments of more than 130 nations, advanced and developing alike, have adopted and are implementing national broadband plans designed to broaden the reach and influence of broadband, according to the United Nations Broadband Commission.

This document explains in greater detail the key indicators associated with the advancement of broadband, points out obstacles related to them, and presents ideas for overcoming these obstacles in a timely manner.

Availability

Framing the issue: Understanding what percentage of individuals, residences and businesses have access to a broadband service in a given area, and what percentage of these entities or individuals is actually connected to an available broadband service provides a starting point for gauging the potential impact of broadband on a community.

Despite widespread agreement about broadband's benefits, access to ubiquitous and affordable broadband services has not yet been achieved for a majority of the world's population.

Despite widespread agreement about broadband's benefits, access to ubiquitous and affordable broadband services has not yet been achieved for a majority of the world's population. The International Telecommunications Union estimated in a 2013 report that 40 percent of the global population would have access to the Internet (mainly via broadband networks) by the end of 2013, but that 1.1 billion households and 4.4 billion people — the majority of the world population — would be without Internet access.[iii]

To be sure, developing nations account for the majority of the non-Internet population. But even in advanced economies, broadband availability is uneven, and there remain pockets of unserved or underserved segments within the United States — the nation with the world's largest number of broadband users — and elsewhere.

In the U.S., for example, an estimated 96 percent of residences had access to broadband networks that provide downstream data at rates of 6 megabits per second or faster as of 2012, according to the National Broadband Map published by the Department of Commerce's National Telecommunications and Information Administration. But even considering this impressive reach, there are several million homes and as many as 15 million people who lack access to fixed broadband networks. (The availability of satellite-delivered Internet service and advanced wireless data networks such as 3G and 4G networks mitigates to some extent the absence of wireline broadband availability among a large percentage of these residences, although generally the performance of wireless broadband is not as robust as the performance of fixed facility networks.)

Broadband availability varies markedly across the world and even within some communities where networks may be available to certain neighborhoods and residences but not others. But it is clearly improving. Although exact data on global broadband availability are not available, the United Nations Broadband Commission believes close to 40 percent of the world's population had access to the Internet as of 2012, with wireless broadband increasingly broadening availability in both advanced and developing economies. Given the steady replacement of early-era dial-up Internet service with broadband alternatives, it is reasonable to assume the large majority of Internet access technologies available today are broadband connections.

Identifying obstacles: Despite the clear momentum for broadband connectivity and usage, there are significant gaps in availability that governments and private industry participants are attempting to address in creative ways. For instance, among the U.S. residences that fall within broadband dark zones, out of the reach of fixed and in some cases wireless broadband networks, many are located in rural communities that risk being left on the sidelines as broadband becomes an essential conduit for education, commerce, entertainment, government and communications resources. According to NTIA's Digital Nation report, 40 percent of rural Americans did not subscribe to broadband at home as of 2011, with 9.4 percent (compared to 1 percent in urban areas) noting a lack of broadband availability as the primary barrier to adoption.[iv]

Developing solutions: Attempts to realize near-ubiquitous availability of broadband are now common among developed nations. The United Nations Broadband Commission counted 133 national broadband plans that governments have instituted through 2012, most of them designed to fulfill a vision of full broadband availability and many backed by significant financial investments in the construction of so-called "last-mile" and "middle-mile" networks that connect users to the Internet at high speeds. The U.S. Broadband Technology Opportunities Program, a multi-billion dollar, government-led effort to fill in underserved areas with broadband networks, is among these initiatives. Beyond the U.S., there is significant effort under way to create near-ubiquitous access to broadband networks through government-encouraged initiatives.

In addition to the policy instruments of subsidization and investment incentives, there are remedies available to further extend broadband's reach. They include:

- Development and exploration of alternative broadband delivery technologies, including TV White Space networks, high-capacity satellite Internet services, experimental high-altitude balloon constellations and other emerging technologies.
- Continued investment in and deployment of broadband-capable advanced wireless networks that serve a widening global population of smartphone and digital device users.
- Permissive local, regional and national regulatory policies that encourage investment by both private and public entities in competitive wireline broadband facilities, including municipal fiber optic networks and privately funded fiber networks.
- Organized community support for the extension of existing broadband networks to unserved and/or underserved residences and/or public locations.
- Public/private partnerships in which municipalities may provide financing for privately operated broadband facilities, for example

These initiatives are united by a faith that extending broadband availability, particularly to underserved areas, encourages economic activity by enabling individuals and organizations to participate in growth sectors of the economy (such as software development, e-commerce and knowledge-based business) and to contribute to technology innovation that leads to job growth.

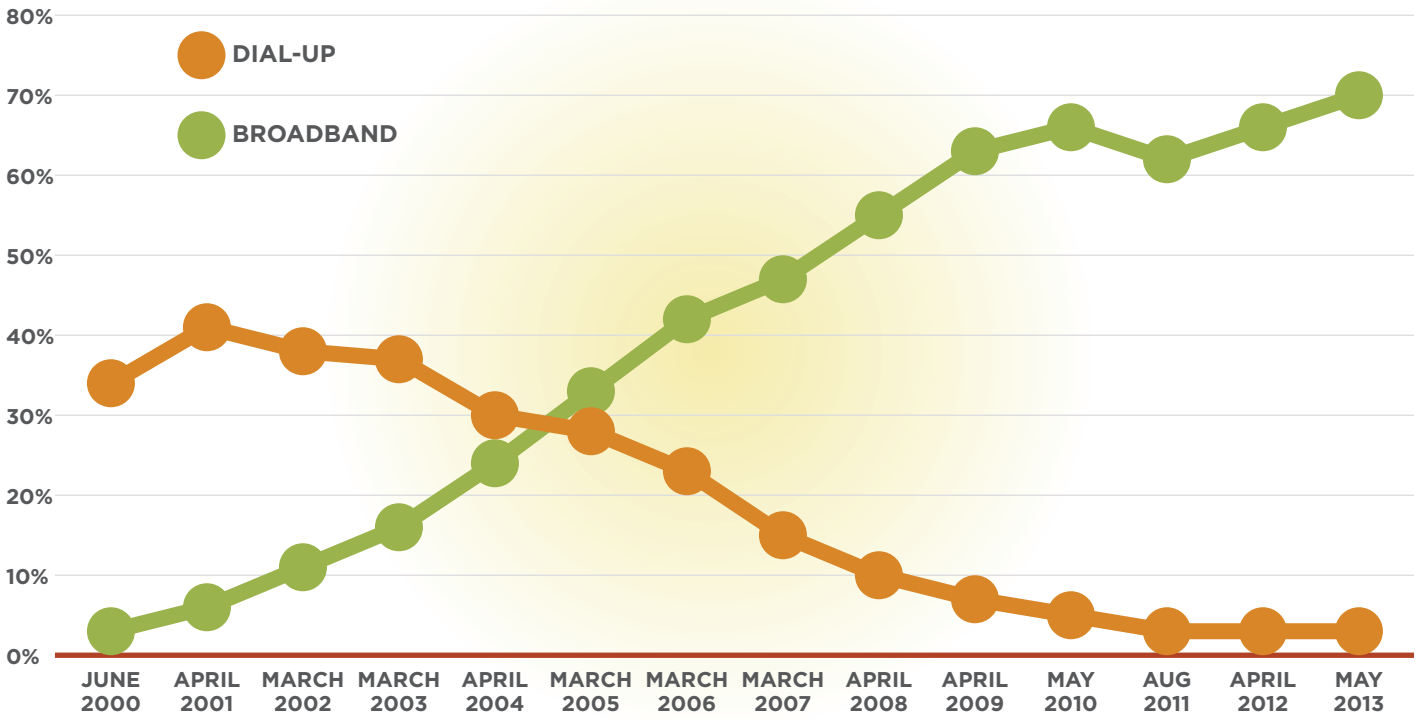
Adoption

Framing the issue: The availability of a broadband connection does not by itself indicate how or whether a broadband network is used. Other factors including interest level, presence of computing devices, digital literacy levels and income vs. cost considerations play into the bigger picture of adoption and usage. Those dynamics help to explain why roughly 70 percent of U.S. households subscribe to a broadband service, despite the availability of broadband in more than 95 percent of U.S. homes, according to the NTIA.

Even so, the adoption curve for broadband has been impressive in the U.S. An August 2013 survey conducted by Pew Research dramatizes the rapid replacement of dial-up Internet service with broadband over a 10-year period.

Home broadband vs. dial-up, 2000–2013

Among all American adults ages 18 and older, the % who access the internet at home via dial-up or high-speed broadband connection, over time. As of May 2013, 70% of adults have home broadband.



Source: Pew Internet & American Life Project Surveys, 2013

At a macro level, there is considerable variation in broadband penetration even among advanced nations, reflecting differences in broadband availability, customer demand, government policy, network performance and household makeup. These variations are reflected in data published by the Organisation for Economic Cooperation and Development, which indicates the number of fixed/wireline broadband subscriptions per 100 inhabitants in Switzerland, the No. 1-ranked nation, was more than 2x that of the 30th ranked nation, Poland, as of December 2012.[v]

Despite the variations among nations and uneven deployment of broadband networks in rural areas of the U.S. and elsewhere, the general trend is toward more people connected to broadband networks, as illustrated by data from the Organisation of Economic Cooperation and Development.[vi]

Wired broadband penetration rates (broadband subscriptions per 100 inhabitants, year end)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Australia	3.49	7.66	13.60	18.28	22.72	24.56	23.01	24.01	24.12	25.20
Austria	7.64	10.61	14.35	16.74	19.25	21.22	21.05	22.83	24.26	24.98
Belgium	11.70	15.54	18.17	22.34	25.57	27.67	28.87	30.84	32.14	33.28
Canada	15.06	17.61	20.73	24.34	27.26	28.23	29.59	30.70	31.70	32.44
Chile	..	..	..	6.14	7.82	8.49	9.71	10.41	11.60	12.40
Czech Republic	0.48	2.50	6.46	11.07	14.54	16.97	12.92	14.56	15.78	16.63
Denmark	13.10	18.96	24.92	31.79	35.64	36.27	36.17	37.23	37.62	38.84
Estonia	..	..	..	16.28	18.78	20.97	22.46	23.28	24.76	24.54
Finland	9.48	14.92	22.39	27.14	30.58	27.89	28.73	28.58	29.49	30.35
France	5.94	10.46	15.07	20.06	24.38	27.64	30.66	32.78	34.68	36.35
Germany	5.59	8.37	12.98	18.19	23.74	27.44	30.46	31.91	33.24	34.06
Greece	0.10	0.47	1.41	4.57	9.69	13.41	16.97	19.90	21.77	23.74
Hungary	1.99	3.57	6.34	9.59	13.88	17.11	17.81	19.56	20.92	21.83
Iceland	14.26	18.20	26.37	28.83	31.45	32.47	32.82	33.65	34.48	34.81
Ireland	0.83	3.32	6.61	12.16	17.45	19.94	19.18	20.65	21.71	22.65
Israel	..	..	..	20.06	21.90	22.70	23.47	23.85	24.20	24.70
Italy	4.13	8.08	11.77	14.24	17.06	18.86	20.02	21.58	22.11	22.15
Japan	10.90	14.96	18.15	20.68	22.46	23.51	24.71	26.57	27.27	27.68
Korea	26.12	27.03	28.69	28.97	30.27	31.61	33.24	34.80	35.88	36.50
Luxembourg	3.46	9.64	14.48	20.99	26.89	29.39	29.19	30.72	31.50	32.11
Mexico	0.42	1.01	2.22	2.84	4.30	7.06	8.68	10.25	10.87	11.64
Netherlands	11.79	18.96	25.22	31.00	34.30	35.61	37.09	38.10	38.93	39.71
New Zealand	2.57	4.72	9.12	11.67	17.85	21.37	22.83	24.85	26.61	28.61
Norway	8.18	15.20	22.62	26.84	30.52	33.71	33.87	34.53	35.22	36.15
Poland	0.78	2.14	2.41	7.18	8.65	10.48	12.83	13.81	14.85	15.21
Portugal	4.81	7.90	11.05	13.45	14.27	15.94	17.98	19.99	21.06	22.55
Slovak Republic	0.35	0.96	2.49	5.08	7.66	11.45	11.59	12.79	13.83	14.77
Slovenia	..	..	..	13.74	16.48	20.77	21.54	22.82	23.76	24.42
Spain	5.41	8.06	11.51	15.11	17.60	20.08	21.31	23.36	24.48	24.65
Sweden	11.15	14.88	20.78	26.22	30.24	31.51	31.63	31.92	31.97	32.21
Switzerland	10.55	17.67	23.85	27.31	32.00	32.73	35.60	38.19	40.25	43.43
Turkey	0.28	0.71	2.12	4.00	6.26	8.07	8.85	9.73	10.25	10.39
United Kingdom	5.39	10.36	16.32	21.45	25.59	28.14	29.46	31.24	32.76	34.25
United States	9.57	12.76	16.32	20.29	23.22	25.48	25.50	26.72	27.70	28.84
OECD	7.18	9.96	13.04	16.92	19.81	21.95	23.04	24.48	25.46	26.29

Source: Organisation for Economic Cooperation and Development, December 2012

NOTE that the OECD data above describe the relationship between fixed/wireline broadband subscriptions and total **population**, which is a different metric than household penetration — a measure of what percentage of **residences** have access to broadband. Although OECD's data provides a good sense of the pervasiveness of fixed broadband within the population of a given nation, the statistics are influenced by independent factors such as how many individuals reside within a given subscription location. (If four people live in a household served by a single broadband subscription, the OECD-reported penetration level would be 25 percent. If a single individual lives in an apartment with a broadband subscription, the penetration level would be described as 100 percent.) For purposes of understanding fixed broadband adoption globally, the data above is most useful in providing directional evidence of broadband's growing presence in daily life.

Identifying obstacles: As the U.S. NTIA pointed out in its report about broadband Internet adoption, "Broadband adoption is more of an issue than the physical availability of broadband. Although we still have problems, primarily in rural areas, with the availability of broadband, the major problem with broadband Internet access in America is the actual use and adoption of broadband in the home."

That observation is underscored by a 2013 finding from Pew Research, which reported that among U.S. adults who do not use the Internet, almost half said the main reason they don't go online is because they don't think the Internet is relevant to them.[vii]

"The major problem with broadband Internet access in America is the actual use and adoption of broadband in the home."

— National Telecommunications and Information Administration

Additionally, many non-adopters are unfamiliar with, and/or skeptical about the Internet at large. They may have concerns about privacy, security and other issues that dissuade its usage, and may lack skills or knowledge about how to safely use the Internet. The NTIA, addressing adoption issues in a document titled the Broadband Adoption Toolkit, observed that "nearly 47 percent of people who do not subscribe to broadband say that they do not need it—there is nothing of interest online for them, or the way they do things now is working fine. These individuals are not aware of the benefits of broadband access or do not understand how Internet use can improve their daily lives."

Developing solutions: If widespread broadband connectivity is an important policy goal — and judging by the fact that more than 130 nations have adopted comprehensive national broadband plans, it is — then broadening the user pool is imperative. Beyond addressing affordability issues which are discussed elsewhere in this document, near-ubiquitous penetration and usage of broadband may be encouraged through combinations of:

- Community and local-market training in digital literacy
- Subsidized (public or private) access to computing devices
- Continued advertising and marketing programs promoting broadband end-user benefits
- Education and outreach efforts designed to share information about Internet/broadband benefits, point to available public computing resources and overcome objections
- Exposure to public broadband resources from libraries, universities and other institutions
- Improved utility for low-use population segments including disabled individuals, the elderly and minority groups

Affordability

What broadband costs

Price per month ($ U.S.) for 15 M/bps and above broadband service by country, September 2012

Chile	$66.62
Mexico	$66.02
Spain	$56.79
Iceland	$48.94
Norway	$48.34
Luxembourg	$47.48
Turkey	$44.94
Ireland	$44.12
United States	$43.99
Canada	$40.86
Sweden	$37.11
Netherlands	$37.05
France	$34.84
Australia	$34.77
New Zealand	$34.47
Czech Republic	$33.33
Switzerland	$33.28
Italy	$33.20
Portugal	$32.97
Finland	$32.45
Greece	$31.55
Japan	$29.73
Belgium	$28.10
Poland	$27.28
United Kingdom	$27.07
Austria	$26.33
Germany	$25.11
Slovenia	$24.35
Israel	$24.19
Denmark	$21.60
Hungary	$20.74
Estonia	$19.23
Slovak Republic	$16.83
Korea	$16.35

Source: Organisation for Economic Cooperation and Development, September 2013

Framing the issue: A key arbiter of broadband adoption is price: How comfortably can a user of average income pay for available broadband services, if at all? Because broadband has become such an important way for people to communicate, engage in commerce and manage their personal lives, broadband is no longer a discretionary line item in many household budgets. Affordability for entertainment purposes and affordability for a necessity of life are different considerations, and play into economic and social evaluations of broadband cost. Even for low-income households, broadband Internet access is a vital component of access to employment opportunities, medical care, community information and other essential resources.

Pew Research's August 2013 survey found that 35 percent of those who subscribe to dial-up Internet service said the price for broadband would have to fall in order to convince them to purchase it.

Identifying obstacles: Price can be an obstacle to broadband adoption for some. According to the NTIA's 2011 Digital Nation report, the second-most commonly cited reason for not subscribing to broadband was "too expensive." ("Don't need/not interested" was the first.) Pew Research's August 2013 survey found that 35 percent of those who subscribe to dial-up Internet service said the price for broadband would have to fall in order to convince them to purchase it. NTIA points out that non-adopters also may have concerns about the confusing and unpredictable nature of broadband subscription costs, or find that the cost of purchasing and maintaining a computer is a barrier to connecting to broadband service.

Others have also identified affordability as an important component of broadband's reach and influence. The United Nations Broadband Commission believes broadband would be considered affordable at a price equal to 5 percent of average gross monthly household income, but notes that actual prices vary greatly. In developed nations, the average cost for broadband service is roughly 1.7 percent of household income, but in developing nations broadband costs account for 30.1 percent of monthly income, making it unaffordable for most potential users. (The OECD-identified monthly cost for broadband service in the U.S. in 2012, at $43.99, is equal to roughly 1 percent of average household income.)

Also, the possibility of a migration to usage-based broadband pricing, in which users pay more as their consumption of bandwidth increases, could elevate real, out-of-pocket costs for broadband service, potentially preventing budget-constrained users from enjoying access to a full range of broadband-enabled services.

Developing solutions: The good news is that broadband has become more affordable in general as combinations of competitive influences, scale economics and in some cases government regulation or subsidization affect pricing. As the United Nations Broadband Commission points out, broadband prices as a share of average income have dropped 82 percent globally from 2007-2012.

Broadband affordability may be influenced positively going forward by factors including:

- **Policies favoring competition.** Regulatory approaches that invite and encourage multiple providers, potentially including municipal network operators as well as private-market competitors, are more likely to encourage affordability.
- **Discounted offers from providers.** Several U.S. broadband providers, for example, offer low-cost (generally $9.95 per month) broadband plans and discounted computing equipment to households that meet eligibility requirements tied to income levels or participation in other recognized programs such as the National School Lunch program.
- **Government subsidies.** Programs designed to partially fund broadband access for underserved communities and/or selected user constituencies may have the effect of widening the user population.
- **Public broadband resources.** Availability of broadband networks and digital technologies in public and community institutions including libraries may provide free or low-cost alternatives to more expensive broadband plans.
- **Regulation.** In markets where competition is absent, the implementation of utility-style regulation with defined return-on-investment parameters may support affordable pricing for entry-level and possibly other broadband services.

Performance

Top broadband performers

Average downstream data rates by country (in megabits per second)

COUNTRY OR REGION	Q1 2013
Global	3.1
South Korea	14.2
Japan	11.7
Hong Kong	10.9
Switzerland	10.1
Netherlands	9.9
Czech Republic	9.6
Sweden	8.9
United States	8.6
Denmark	8.2

Source: Akamai State of the Internet Q1 2013

Framing the issue: Not all broadband networks are created alike. Although the U.S. Federal Communications Commission's definition considers any downstream delivery network operating at 4 Mbps or greater to constitute a "broadband" connection, application performance and user experiences are considerably different at, for example, 20 Mbps or greater. Other performance factors such as latency and packet loss also have a perceptible impact on end-user experience, as does network upstream speed, which is important for applications involving the uploading of data and files to "cloud" server facilities or other users.

Even so, raw data delivery rates are widely viewed as indicators of broadband network capability and often play into competitive marketplace considerations among consumers. This need for speed of a broadband connection is driven by multiple influences including:

- The number of broadband enabled devices connected, which is growing exponentially
- The types of applications being simultaneously used
- The speed requirements of the applications is ever increasing
- The real-time requirements of the application (or alternatively how much delay can the application tolerate before it is deemed non-operational)

Many observers believe gigabit networks are the key to developing a more holistic suite of integrated applications that transcend today's broadband capabilities.

Broadband speed requirements also are driven by high-value entertainment applications such as high-definition video streaming that requires high bit rates.

Also, an important parameter is the sustainable speed when the network is under normal user load and not the maximum available speed which might be available only during times that are normally not used by the average person, for example at 3 a.m. Finally, depending on the technology and how it is implemented there can be one or more choke points in a user's path that prevents the advertised speed of the service to be achieved.

There is particular promise around the leap from multi-megabit per second data rates to gigabit speeds that can transform the Internet experience in ways that users, network providers and application developers are only beginning to contemplate.

A data delivery rate of 1 gigabit per second is 100x faster than the 10 Mbps speed that is widely considered today to represent a robust broadband capability. Translated to familiar tasks, this performance increase is striking. For example, it would take about seven seconds to download a high-definition movie over a 1 Gbps network, versus close to 11 minutes over a 10 Mbps connection. Moreover, downloading the same 100 digital photographs that require more than four minutes over a 10 Mbps connection takes only about seven seconds over a 1 Gbps network.

But the gigabit network promise goes beyond favorable performance comparisons for existing and relatively simple applications. Many observers believe gigabit networks are the key to developing a more holistic suite of integrated applications that transcend today's broadband capabilities. Commonly cited examples include immersive multimedia experiences, massive data transfer, three-dimensional imaging and modeling and "presence" applications that allow individuals to engage and interact with others in ways that even today's high-definition conferencing experiences cannot match. (A broader list of examples appears in *Appendix: Advanced Broadband Services*.)

Fiber connections as % of total broadband subscriptions
(December 2012)

Israel	0.00%
Mexico	0.00%
Belgium	0.07%
Greece	0.10%
Ireland	0.51%
New Zealand	0.65%
Chile	0.74%
Germany	0.75%
Austria	1.27%
France	1.32%
Australia	1.59%
Canada	1.71%
Italy	2.14%
Finland	2.50%
Spain	2.97%
Luxembourg	3.33%
Poland	3.35%
United Kingdom	5.00%
Netherlands	5.97%
Switzerland	6.68%
United States	7.36%
Turkey	8.21%
Hungary	14.71%
Portugal	15.17%
Czech Republic	15.55%
Denmark	17.21%
Slovenia	17.82%
Iceland	20.17%
Norway	22.18%
Slovak Republic	31.23%
Estonia	32.19%
Sweden	33.72%
Korea	61.17%
Japan	66.72%
OECD	14.88%

Source: Organisation for Economic Cooperation and Development, September 2013

Gigabit networks have the potential to fundamentally shift the Internet experience into something more intuitive and facile than prevailing broadband networks can accommodate. A telling comment, reported in a May 2013 *Forbes* magazine article, came from a user of CenturyLink's 1 Gbps broadband network in Omaha, Neb. The user said the experience made it seem as if the Internet was "invisible."

Indeed, similar to the way modern electric utility networks provide power for myriad uses and applications with almost no user intervention or second thought, gigabit broadband networks promise to make the Internet a more facile, useful and powerful tool for everyday life.

It is for these reasons that a rising movement is under way to find ways to encourage the construction and deployment of gigabit networks. Israel, for example, has pledged to make gigabit Internet access available to all citizens through an orchestrated national broadband program. The UNH BCoE advocates for a similar policy to prevail in the U.S. as a goal for achieving fuller benefits of broadband. There is some momentum building now in pursuit of this goal. A number of U.S. cities, inspired by reports of an early and successful implementation of a gigabit network in Chattanooga, Tenn., have initiated or launched gigabit networks. And private market entrants in the U.S., including Google, Comcast, CenturyLink, Time Warner Cable and other telecommunications companies, have elevated interest and awareness around the possibilities of gigabit networks by launching construction and deployment of 1 Gbps networks in selected cities.

Identifying obstacles: Capital investments required to build and maintain fixed broadband networks tend to dissuade multiple participants from competing for users, possibly reducing competitive pressures to upgrade network performance in certain markets and/or instances. Even so, the recent history of broadband is one of ongoing performance improvements. In OECD-member nations, for example, the average downstream speed delivered by fixed broadband networks had improved to 3.1 Mbps in 2012.

Developing solutions: Combinations of private-market incentives and policy that favors multiple entrants in the form of both private and public sector participants may result in more rapid deployment of higher-performance networks. For example, in U.S. markets where Google, Verizon and others have initiated or announced plans to offer high-performance broadband services, incumbent telecommunications providers have responded by upgrading networks to offer similar performance. Also, government-directed spectrum allocation approaches that aid in the development of robust wireless broadband networks can contribute to a competitive marketplace that yields end-user benefits in network performance.

A key enabler of forward progress in broadband network capability is fiber optics, a transmission medium that is capable of achieving enormous signal throughput and, coupled with advanced electronics and end-user processing systems, can support order-of-magnitude improvements in broadband network performance.

A variety of last-mile connectivity options can and should flourish. These include wireless LTE networks, hybrid fiber-coaxial networks, digital subscriber line (DSL) networks, TV White Space networks and satellite Internet. But a concerted focus on the construction and deployment of high-speed fiber optic networks to end users directly, or to nearby serving areas toward the edge of networks, appears to be the most promising avenue for yielding the full benefits of broadband.

Utilization

Cisco estimates global IP traffic at large will rise to an annual run rate of 1.4 zettabytes by 2017, representing a 3x increase from 523 exabytes estimated in 2012.

Framing the issue: Knowing the percentage of available broadband network resources that are used within a geography contributes to an understanding of how adequately a community is served by broadband and whether additional bandwidth may be necessary to support current and future needs.

Capacity planning — estimating bandwidth demands and developing provisioning plans to suit them — is an inexact science, influenced by estimates of future behavior that are uncertain. But the general consensus among broadband network providers is that bandwidth requirements continue to grow rapidly as users extend the amount of time they spend using broadband applications, adopt higher-bandwidth applications such as media streaming and file sharing and connect more devices to broadband networks.

As one indication, networking technology provider Cisco estimates global IP traffic at large will rise to an annual run rate of 1.4 zettabytes by 2017, representing a 3x increase from 523 exabytes estimated in 2012. (A zettabyte is equal to 1 billion terabytes.) This rapid progression both reflects and depends on increasing capabilities of broadband networks. Cisco estimates average global broadband speed will grow 3.5-fold, from 11.3 Mbps (2012) to 39 Mbps (2017).[viii]

Global IP traffic by application (petabytes per month)

	2013	2015	2017
Business file sharing	750.6	969.0	1158.0
Business video	3659.3	7039.3	12277.5
Business web and data	6120.4	7408.9	8288.9
Consumer web and data	6336.4	9541.7	14494.1
Consumer file sharing	7118.8	8266.1	8667.3
Consumer video	31541.4	50571.5	75697.9

Source: Cisco Visual Networking Index, May 2013

Identifying obstacles: Network providers and those responsible for planning for community broadband must take into account the likelihood of significant increases in demand for bandwidth. Planning exercises are made difficult, however, by the inability to know with precision what mix of applications, usage trends and technology advancements may influence bandwidth consumption and network utilization.

Developing solutions: An open exchange of data, exemplified by publicly available resources such as Cisco's Visual Networking Index and similar estimation tools, can contribute to intelligent planning for network capacity and utilization. Additionally, communities and broadband planning agencies may benefit from:

- Encouraging or insisting on the deployment of excess capacity in newly constructed broadband network facilities, such as the inclusion of "dark fiber" lines that may later be activated as demand rises.
- Encouraging the more efficient and scalable use of existing networks, automatically identifying and removing bottlenecks, and deploying 'intelligent' networks (such as those employing software defined networking).
- Requiring franchised or licensed providers to disclose available data around network utilization and capacity at regular intervals as a means of assessing the adequacy of existing facilities and making intelligent planning decisions for community needs.

Ease of use

The same sort of take-it-for-granted reliability that prevails in electricity must emerge as a constant attribute of broadband.

Framing the issue: Incremental speed improvements won't elevate broadband to a level of performance that matches what users have come to consider — or perhaps to take for granted — from staples of modern life such as electricity.

To realize a fuller potential, the broadband network of the future must deliver near-faultless performance, be available at all times to any connected device or application and essentially operate reliably in the background of everyday life, much like electricity does today in advanced nations. Intuitive, menu-driven applications that make broadband use simple and appealing across all generations are critical for widening usage and utility. Similarly, broadband devices must become as easy to use as common household appliances, with familiar controls, functionality and consistency achieved through incorporation of standards and interoperability.

Identifying obstacles: Even as broadband speeds and performance have increased significantly since the introduction of the first large-scale consumer broadband networks in the early 2000s, there is still a disproportionate demand for user attention to issues such as complicated device installations, network discovery, file download times and occasional lapses in connectivity.

These are performance degradations modern society would find unacceptable from electrical delivery networks. Instead, we flip switches, lights illuminate, and we think nothing of it. The same sort of take-it-for-granted reliability must emerge as a constant attribute of broadband if we are to achieve the profound advances in productivity, creativity and economic growth that many believe broadband promises.

The ease-of-use imperative will only rise in importance as broadband network users connect more devices to their networks. As Merrick Kingston, a senior analyst of broadband technology at the research firm IHS has pointed out, "We're quickly approaching a world where the average broadband household contains 10 connected, video-enabled devices. This means that each TV set installed in a broadband-equipped home will be surrounded by three Internet-connected devices."

Developing solutions: Ease of use is now a mantra among application and digital device developers that have identified simplicity and intuitive functionality as important competitive differentiators. A similar mentality must come to prevail in the broadband provider community.

Some providers are making progress in helping customers manage in-home networks and service experiences tied to the connectivity these providers supply. Their motivation is partly rooted in a desire to achieve competitive differentiation and improved market share — goals that are more likely to be present under regulatory systems that promote and encourage a multiplicity of providers in the broadband arena. Absent these marketplace dynamics, ease of use is less likely to receive investment and operational priority from private market providers and may require enforcement through regulatory means.

Services

Framing the issue: A final obstacle to a fuller realization of broadband's potential involves the services and applications available to broadband network users. Although an impressive range of services flow over today's multi-megabit per second networks — and more are invented by the week — a forward leap in software performance and ease of use is needed to fuel the 21st Century's connected economy.

A contrary view is that performance limitations of prevailing broadband networks constrain a richer set of applications that otherwise could emerge.

The relationship between broadband services and network capabilities presents a modern-day "chicken-and-egg" conundrum. Defenders of today's broadband status quo — with its multi-megabit networks, generally permissive monthly usage caps and solid market penetration — argue that today's prevailing networks are perfectly adequate for delivering the range of services consumers value the most. These are generally high-performance iterations of Internet services originally invented or conceived during the early days of narrowband IP networks — the so-called "dial-up" era of the Internet. For example, today's high-definition video entertainment services are successors to early-stage experiments in media streaming over the Internet, and today's multimedia-enhanced e-commerce platforms are logical followers to the early-era online shopping sites that sprang to life in the early 2000s. This viewpoint, which has been expressed by some incumbent broadband network operators, suggests that today's relatively robust broadband networks perform admirably for the large majority of users and available applications.

A contrary view is that performance limitations of prevailing broadband networks constrain a richer set of applications that otherwise could emerge. This perspective is reflected in comments from an executive of Google, who observed in a 2013 *Government Technology* article that "If you look at innovation of Web services right now, we're kind of hitting the ceiling imposed by today's Web speeds...engineers have these great ideas for products that they want to deploy to customers, but Web speeds are just draining their ability to do that."

A reckoning of these opposing perspectives may be required to invite a more robust implementation of applications, services and capabilities that rely on — and compel improvements to — broadband technology. The ideal environment for broadband services is a virtuous cycle in which more capable broadband networks inspire highly compelling and useful applications, and in which more compelling applications inspire investments in improved network performance.

A useful analogy may spring from the transportation sector. When high-speed, multi-lane highways originally were conceived and constructed in the U.S. during the 1950s, the inspiring vision was a reliable means to move military vehicles and citizens in the event of a military attack. Few people envisioned the vast cultural, economic and social change that would arise because of widespread access to affordable transportation for massive numbers of individuals. It was the product of an enabling agent — public roads — coupled with innovation around products (vehicles, mainly) which transformed entire societies. In turn, steady improvements in automobile performance and affordability compelled the construction of more and better highways and roads.

Similarly, innovative broadband applications and creative ways to implement them represent a positive force that has the potential to pull the broadband ecosystem toward a gigabit environment that supports the vision of a robust information age, one in which individuals and organizations are presented with profound new capabilities for civic, social and economic participation. It's possible that many of these newer services will have meaningful impact on the 21st century economy as a complement, or in some cases a successor, to legacy industrial economy activities.

Identifying obstacles: Several factors frustrate more rapid innovation around advanced broadband applications. As mentioned, applications must contend with network performance constraints that demand workarounds or in some cases may halt development altogether. (The implementation of adaptive video streaming approaches that may intentionally degrade video bit streams to match the available performance of a user's broadband network is one example.) Another limitation involves complexity. Although it's easier than it used to be to create and publish content over the Internet, for example, more elaborate applications demand significant investment in software development that produces entry barriers for creative people with worthy ideas. Finally, an absence of collaboration among broadband ecosystem participants, from network operators to device manufacturers, can frustrate product innovation.

Developing solutions: Innovation around next-generation broadband applications already is happening. At the individual application level and in the rise of fully networked organizations such as Amazon, the possibilities of an integrated broadband ecosystem are becoming more visible. But the pace of next-generation application and service development can be hastened by adopting new approaches that may include:

- **More help for entrepreneurs.** Educational forums and/or information exchanges that assist creative visionaries in understanding the requirements and possibilities of broadband application development can erase months or years of ramp-up time.
- **Strong resolve from policymakers.** Gigabit networks are the key enabling agents for new breakthroughs in services and applications that can provoke economic growth and contribute to social welfare. In areas where development and implementation of gigabit networks is wanting, governments should consider methods of triggering or encouraging investment.
- **More accessible toolkits.** Removing complexity and cost from the task of developing broadband services can accelerate the virtuous cycle of innovation and network performance enhancement that will foster the fuller realization of broadband's potential. Borrowing from the successful application development models that mobile device makers have implemented is essential to widening participation in the broadband services ecosystem.
- **Greater collaboration.** Compartmentalizing applications and services into standalone silos is the enemy of a truly integrated broadband ecosystem. Wide collaboration must occur across markets and within organizations to realize the benefits of integrated systems that deliver intelligent automation to users.

Target: 2020

Realizing the full benefits of broadband requires identifying and implementing solutions to the seven areas of focus identified in this document.

Broadband is more than a faster way to summon streaming media content, make phone calls over the Internet or complete e-commerce transactions more efficiently. Robust broadband connectivity promises to connect and empower individuals in ways we can scarcely imagine today. It is a new alphabet that has the potential to transform consumers into creators, to ease environmental strains, to improve economic and social conditions for people and for entire nations. It is a powerful, noble tool for improving the quality of life — so much so that it may be advisable for governments to establish high-level advisory departments or agencies that are tasked with coordinating and advancing broadband resources and programs in a role similar to that of the U.S. National Aeronautics and Space Administration in space exploration.

But getting there — realizing the full benefits of broadband — requires identifying and implementing solutions to the seven areas of focus identified in this document:

- **Availability:** Development and exploration of alternative broadband delivery technologies; continued investment in and deployment of broadband-capable advanced wireless networks; permissive, investment-encouraging regulatory policies; and organized community support.
- **Adoption:** Community and local-market training in digital literacy; subsidized (public or private) access to computing devices; continued advertising and marketing programs promoting broadband end-user benefits; exposure to public broadband resources from libraries, universities and other institutions; and improved utility for low-use population segments including disabled individuals, the elderly and minority groups.
- **Affordability:** Discounted offers from providers to price-sensitive market segments; government subsidies for underserved communities and constituencies; regulatory approaches that encourage competition; and access to free broadband connectivity in public and community institutions.
- **Performance:** Economic and regulatory policies that favor multiple entrants and encourage competition; coupled with a focus on extension of high-performance fiber optic networks to neighborhood serving areas and/or end user locations.
- **Utilization:** Open exchange of network usage data that supports informed capacity planning; investments in excess capacity through newbuild networks; and requirements from licensors or franchisors to have access to data around network utilization and capacity.
- **Ease of use:** Encouragement of multiple providers through policies that promote competition in facilities ownership and operation; open access to broadband networks for application developers and end users; and in the absence of competitive influences, regulatory policies that demand performance and service standards.
- **Services:** Educational forums and information exchange; deployment of gigabit networks; improved collaboration among disparate market participants and within organizations.

Broadband champions representing the full spectrum of participants, from network operators to application developers to policy makers and community leaders and others, are critical to achieving these solutions in a rapid time frame. A dedication to advancing awareness, availability, understanding and application of a technology that has the potential to bring about lasting, positive change for the world at large is critical.

The UNH Broadband Center of Excellence is dedicated to solving the key obstacles that are preventing more rapid progression of a global broadband marketplace enabled by gigabit-capable networks, and doing so by 2020. Working with a broad range of partners, the UNH Broadband Center of Excellence is dedicated to energizing broadband's advancement within the University System, within the state, within the United States and around the world.

Appendix: Advanced broadband service examples

Broadband services and the software that powers them have potential to propel the 21st Century economy through advancements that were once unimaginable across a wide range of categories and emerging digital communities. These examples illuminate some of broadband's profound possibilities.

Education

In the U.S. and other developed nations, there is a growing gap between the requirements of new jobs being created and the qualifications of many job seekers. Broadband can help address this disparity by enabling:

- Qualified broadband training centers that can both connect people to new opportunities and train them to be qualified for an emerging segment or industry
- Convenient, easy access to books, published research, scientific data or course materials in any language available
- Access to museums and cultural centers via video and multimedia resources
- On-demand lectures available anywhere and anytime
- Interaction with knowledge centers and experts in areas of interest
- Online digital textbooks, libraries and virtual classrooms
- A broadband academy regimen for students, faculty, and staff, providing a base knowledge of broadband technology that will become necessary in many areas of education and commerce
- Collaboration among faculty, students, and staff, uniting them through research, scholarship and innovation
- Executive training programs to provide valuable supplemental knowledge and experiential learning that aligns students with broadband industry participants and delivers training in broadband technologies
- Intelligent technologies within classrooms that allow for distance learning and collaboration

Health Care

Broadband has the ability to enable higher quality care, lower costs of care and improved interaction between patients and providers by providing:

- Secure digital access to records, medication histories and other vital data
- Networked diagnostic tools and laboratories
- Remote monitoring of home-bound patients
- Remote observation and interaction with medical professionals in the performance of surgical procedures
- Remote public health consultation
- Interaction between emergency response mobile units, remote doctors and emergency facilities

Community

Aligning broadband capabilities with the needs of communities, companies and residents will contribute to local economic growth, education, job creation, public services and infrastructure improvements. Examples include the ability to:

- Watch and participate in local, state and federal government meetings
- Interact with community officials
- Access government documents and files
- Link intelligent buildings to smart power grids to reduce energy consumption through real-time load monitoring and adjustment
- Collaborate with like-minded entrepreneurs, colleagues and mentors
- Enhance rural communication resources and provide access to critical services
- Dynamically connect emergency responders
- Monitor traffic in real-time and optimize traffic conditions
- Improve community planning and collaboration

Automation

Machine-to-machine connectivity for every device in every location in the world will enable intelligent infrastructure for the benefit of society. While the broadband focus is on connecting 7 billion people, the even bigger challenge is secure and low-cost machine-to-machine connectivity among billions of devices, creating new possibilities for understanding, analyzing and influencing our physical environment. Possibilities include:

- Secure entry, motion detection, humidity, temperature and carbon monoxide sensors in buildings
- Maximize energy efficiency and climate control by managing appliances and energy consumption
- Monitoring home security dynamically
- Managing home devices and appliances remotely
- Monitoring locations and activities of children anywhere and on device, securely
- Attaining live remote service from experts for repair and maintenance
- Conserve water through remote management of irrigation systems

Commerce and Communications

Broadband supports technologists, educators, content creators and community leaders in advancing their specialties across a wide range of personalized applications. Examples include:

- Participation in telecommuting, tele-presence and video conferencing
- Enhanced social networks using broadband-intensive applications including image and video sharing
- Live and on-demand streaming of lectures, concerts, and performances
- Access to vast entertainment libraries available on demand
- Secure entry to your homes based on visual/facial identification
- Immersion in 3D worlds including publishing and printing
- Custom design and test-driving of automobiles
- Live family interaction from remote locations

Government

Extending broadband infrastructure to better support emergency responders is a critical need. Connecting safety agencies, environmental management offices and other government entities will provide for more efficient dissemination of data to scientists and public safety workers, allowing for faster response efforts to disaster and/or environmental conditions. Sample applications include:

- Collaboration with elected officials and conveyance of personalize points of view
- Use of cameras and detectors to enhance community security
- Improvements in government efficiency and cost-of-services reduction
- Access to government data and forms
- Dynamic monitoring of environmental impacts via sensor-based devices
- Emergency and disaster alerts and pro-active response
- Paperless processing of state and federal grants
- Community notification and emergency alerts
- Sensor-based weather and agricultural information systems

The above list is hardly exhaustive. Rather, it's intended to suggest the range of possibility broadband enables for enhancements in the way people live, work, communicate and play.

Endnotes

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