Mobile Broadband and Implications for Broadband Competition and Adoption

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William Lehr
Massachusetts Institute of Technology

Executive Summary

The growth of wireless mobile broadband has the potential to drive significant new growth in Internet applications, services, and equipment markets. It is likely to represent as important a change for the Internet as the transition from dial-up to broadband, fundamentally changing the landscape for broadband Internet access by adding the mobility that is needed to enable truly ubiquitous and pervasive "always on" Internet services. Incumbent operators like AT&T, Verizon, Sprint, and T-Mobile, and new operators like Clearwire and Cox are investing billions of dollars to expand coverage and enable much higher quality mobile broadband services. Mobile broadband subscribership and the Internet traffic it generates are growing rapidly and these trends are expected to continue into the future.

While mobile Internet availability and usage are growing quickly, the primary forms of broadband Internet access today use fixed-access connections, chiefly from telephone and cable companies. Although we are still in the early stages of the development of mass-market mobile broadband and the fuller development of the mobile Internet that it portends, it is reasonable to speculate about what the likely implications of mobile broadband will be for broadband service markets and for the dynamics of broadband service competition and, therefore, broadband adoption.

In this paper, I survey current data on emerging trends to inform a vision of what the near-term future (3-5 year horizon) for mobile and fixed broadband is likely to look like. This analysis confirms the conclusion that mobile broadband will drive growth and provide a stimulus for innovation and investment for broadband infrastructure and the Internet overall. In the first instance, mobile broadband will bring us a step closer to the vision of pervasive, always on, everywhere connected computing and communications that will significantly enhance the value proposition of using Internet services. This should result in a rightward shift of individual and aggregate demand across the full spectrum of user types and stimulate the emergence of niche and value-added service markets (e.g., mobile healthcare, mobile e-Commerce, and location-aware services). These demand stimulus effects are pro-competitive since they expand revenue opportunities for incumbents and entrants alike, and should contribute to promoting adoption and usage rates.

[1] The author would like to acknowledge the financial support of Broadband for America (see http://www.broadbandforamerica.com/). All opinions expressed herein are those of the author alone.

Because it is reasonable to expect that mobile and fixed broadband will continue to be characterized by different service features, I expect that mobile and fixed broadband services will be perceived as distinct and complementary services, rather than as close service substitutes in most user/usage contexts. However, for some subscribers and in some contexts, mobile broadband may be perceived as an acceptable substitute and thereby mobile services will impose a degree of (intermodal) competitive discipline on broadband service markets in general, and on fixed broadband services more specifically. It is likely that mobile broadband will provide most direct competitive pressure on first-generation, lower-quality fixed broadband services. Competition from mobile broadband is also likely to encourage and accelerate upgrade investments in fixed broadband infrastructures as providers seek to differentiate their offerings by accentuating the relative advantages of fixed-access services. These effects contribute to the conclusion reached herein that the overall impact of mobile broadband will be strongly pro-competitive.

1. Introduction

The growth and pervasive use of Information and Communications Technology (ICT) has transformed our global economy and society over the last half-century. Fueled by Moore's Law improvements in the price-performance capabilities of computers, computing has expanded from mainframes to desktop computers to embedded processors that are ubiquitously deployed in all kinds of devices and appliances. These computing resources are made more valuable when networked via data communication services. During the 1980s, desktop computing and local area networking spread across all industrial sectors and businesses of all sizes, and personal computers became increasingly common in homes. During the 1990s, two parallel but related phenomena moved us closer down the path towards the future of pervasive computing: the explosive growth of both mobile telephony and the Internet. During the first decade of the 21st Century, broadband access became *the* dominant mode for Internet access in the United States, bringing "always on" connectivity and higher data rates to support rich media and Web-2.0 enabled interactivity to the Internet.

Now, as we prepare to enter the second decade of the 21st century, we are on the cusp of realizing the convergence of the broadband Internet and mobile communications with the widespread deployment and adoption of mobile broadband services. The convergence of mobile communications and the Internet will bring us a step closer to realizing a vision of pervasive computing and communications, where the power and capabilities of ICT can delivery true 24/7, everywhere/always connected ubiquitous computing and communications services. This convergence has the potential to be as transformative and growth producing as those earlier transitions.

While the availability and usage of mobile broadband services are expanding rapidly, we are still in the early stages of the emergence of the mobile broadband future. Today, most consumers access the Internet via fixed-location broadband connections, provided over wired infrastructures via cable or DSL modems. However, in anticipation of the evolution of mobile broadband services, it is worthwhile considering what the implications may be for broadband services in general, and more specifically, for prospects for competition in broadband service markets. In the balance of this paper, I will explain why I believe it is reasonable to expect the overall impact of mobile broadband to be strongly pro-competitive with regard to the Internet and broadband service markets generally.

The expansion of mobile services will substantially enhance the value proposition for Internet access, supporting wholly new services as well as expanding the usability of existing services. The market growth stimulus associated with these effects is expected to be quite significant. At the same time, the growth of mobile broadband will have complex implications for broadband competition and on broadband services offered via fixed-access connections. As I will explain, I expect fixed and mobile broadband services to offer distinctly different sets of basic capabilities, and as a consequence, to remain distinct services that will not be perceived as close substitutes in most user/usage contexts for the foreseeable future.

It is likely that mobile broadband services will generally offer lower data rates and confront higher traffic sensitive costs than fixed broadband services. Offsetting these comparative disadvantages, however, mobile broadband services will offer the important *killer app* functionality of 'mobility' in all of its flavors. I expect the growth of mobile broadband to impose competitive discipline on lower-quality, first generation fixed broadband services; at the same time, it will encourage providers of fixed access services to accelerate investments in enhancing the quality of fixed infrastructures to enable those services to better compete against improving mobile broadband services and to better accommodate the traffic generated by mobile users. The competition at the low-end and the spur to investment in higher-quality fixed broadband services provide further support for concluding that the likely impact of mobile broadband will be strongly pro-competitive.

In Section 2, I evaluate current trends in order to further flesh out a vision of the mobile broadband future that is emerging. Section 3 addresses what this is likely to mean for mobile-fixed broadband competition. Section 4 offers conclusions and discusses some of the policy implications.

2. Emerging mobile broadband future

Before focusing on the mobile broadband future, it is worthwhile spending some time looking at the structure and performance of mobile services in the United States overall. As I will explain, the evidence demonstrates that these are robustly competitive.

2.1. Competition in mobile services

Mobile telephony services were first launched in the mid-1980s as analog, first generation or "1G" services. In their early incarnation, coverage and capacity were limited. Service was targeted for in-car use along major highways as a high-price (luxury) service with relatively poor quality. Handsets were large, expensive, and power-hungry. Still, the promise of mobile communications was sufficiently compelling so the market grew rapidly. The second generation ("2G") services were launched in the mid-1990s as digital technology replaced analog and mobile telephony emerged as a true mass-market service. The switch to digital made it feasible to expand capacity, coverage, and improve call quality.[2] Growth accelerated and during the 1990s, mobile telephony penetration soared from slightly less than 13% in 1995 to over 50% by 2003.[3] There are now over 276 million mobile phone subscribers in the U.S., representing a penetration rate of 89%.[4]

These subscribers are served by a diverse array of facilities-based and non-facilities-based service providers. In addition to the four largest national providers (AT&T Wireless, Verizon Wireless, Sprint-Nextel, and T-Mobile),[5] there are a number of large regional providers (e.g., US Cellular, Leap Wireless, and MetroPCS),[6] and a large number of service resellers (e.g., Firefly, Virgin Mobile, and Tracfone).[7] There are also new facilities-based wireless providers like Clearwire and Cox Communications. Clearwire was launched in 2008 with the goal of providing WiMAX-based fixed and mobile broadband wireless services -- including telephony services. Clearwire is on track to provide coverage to 40 million POPs by the end of 2009, and was already serving 511 thousand customers by the end of June 2009.[8] Cox Communications,

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[2] Digital technology makes it easier to use the spectrum more efficiently.

[3] Penetration in the U.S. was 10.7% in 1995 (=33.8 million subscribers divided by 262 million population) (see *13th CMRS Report*). Worldwide, mobile penetration was 5.34% in 1998 and 59.62% in 2008 (see ITU World Telecommunications/ICT Indicators Database, available at: http://www.itu.int/ITU-D/ICTEYE/Indicators/Indicators.aspx.)

[4] As of June 2009. See CTIA—The Wireless Association (2009), "Wireless Quick Facts: Mid-Year Figures," available at: http://www.ctia.org/advocacy/research/index.cfm/AID/10323.

[5] Collectively, the largest four providers provide service to 89% of subscribers, with the largest providing service to 31.6% of subscribers as of March 2009. The 4-firm concentration ratio is the lowest among the OECD countries, with only the United Kingdom (93%), Canada (98%), and France (98%) below 100% (see, Ehrlich, Everett, Eisenach, Jeffrey A. and Leighton, Wayne A. (2009), "The Impact of Regulation on Innovation and Choice in Wireless Communications," September 2009 (available at: http://ssrn.com/abstract=1478528). Because of the high fixed costs and capital intensity of constructing and operating a mobile telephone network, including the cost of acquiring spectrum licenses, we should expect to see a relatively high-level of concentration. In light of these challenges, the level of facilities-based competition we see in wireless services is remarkable.

[6] These regional providers each serve millions of subscribers: US Cellular (6.2 million subscribers, 84 million POP coverage); Leap Wireless (4.5 million subscribers, 91 million POP coverage); and MetroPCS (6.3 million subscribers, 87 million POP coverage). (Subscriber counts and POP coverage as of June 2009).

[7] Mobile Virtual Network Operators (MVNOs), or resellers, provided service to more than 18 million subscribers as of the end of 2007 in the United States, and there were about 55 active MVNOs in the US at the end of May 2008 (see paragraphs 17-18 of *Thirteenth Report*, In the matter of Annual Report and Analysis of Competitive Market Conditions with Respect to Commercial Mobile Services, Federal Communications Commission, WT Docket No. 08-27, January 16, 2009, hereafter, *13th CMRS Report*).

[8] Clearwire was spun-out of Sprint-Nextel in November 2008 as an independent company, with significant investment participation from Sprint-Nextel, Google, Intel, and Comcast (see "Clearwire Reports Second Quarter 2009 Results," available at: http://investors.clearwire.com/phoenix.zhtml?c=198722&p=irol-newsArticle&ID=1319734&highlight= and Clearwire 10Q, August 2009).

best known as a cable company, purchased spectrum licenses at auction and is in the process of building out a 3G/4G mobile network.[9] Today, over 90% of the population now lives in Census blocks served by four or more mobile operators.[10]

Collectively, these providers have been investing and continue to invest tens of billions of dollars every year in expanding their network coverage and upgrading the quality of their infrastructure. According to the CTIA, cumulative wireless industry capital expenditures since 1985 exceeded $264 billion, or more than $22 billion per year.[11] The number of cell sites has grown almost 10-fold since 1995, to over 213 thousand by 2007.[12]

The expansion of facilities-based networks has intensified competition, resulting in continuously falling prices. Roaming charges have fallen,[13] pre-paid and unlimited calling plans and feature-rich options have expanded,[14] and handset prices have fallen[15] (while handset subsidies have remained high).[16] From 1994 to 2007, the average revenue per minute fell 87%.[17] Although average monthly bills for mobile service have remained approximately constant, close to $50 per month, usage has soared.[18] And, in July 2009, TracFone forged new pricing ground with its national unlimited calling plan for only $45 per month.

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[9] See "Cox to launch Next Generation Bundle with Wireless in 2009," Cox Communications Press Release, October 27, 2008 (available at: http://www.coxcommunications.com/oklahoma/presscenter/pdf/102708_wireless_bundle_09.pdf).

[10] 90.5% of the population live in Census blocks with 4 our more operators, and 64.9% with 5 or more operators. 99.6% of the population live in Census blocks with at least one operator (covering 74.5% of the land area). (See Table 1 in *13th CMRS Report*.)

[11] See CTIA Semi-Annual Wireless Industry Survey and U.S. Census data.

[12] There were 22,663 cell sites in 1995 and 213,299 by 2007 (see, Table A-1, CTIA Semi-Annual Mobile Telephony Survey in *13th CMRS Report*).

[13] Roaming accounted for 10.8% of carrier revenues in 1997 and only 2.7% in 2007 (see Table A-1, *13th CMRS Report*).

[14] Pre-paid calling rose to 19.5% of the market as of the June 2009 (see “Telecom Services: Unlimited Prepaid Wars Heating Up,” Morgan Stanley Equity Research, August 10, 2009).

[15] Handset prices have fallen, although the average handset price has not because a larger share of handsets are now more expensive smartphones.

[16] The average handset subsidy in the U.S. was $104 (over 12 months), with subsidies representing a smaller share of the total price for more expensive smartphones (see,

[17] The average revenue per minute fell from $0.47 to $0.06 (see paragraph 193 o the *13th CMRS Review*). Furthermore, from 1997 to 2007, the cellular CPI fell 35.6% while the overall CPI rose 29.2% (see Table 11 of the *13th CMRS Review*).

[18] The average monthly bill for mobile phone service was $51.00 in 1995 and $49.79 in 2007, but minutes of use grew from less than 150 MOU per month in 1995 to 769 MOU per month by 2007 (see *2nd CMRS Report*, footnote 256, and *13th CMRS Report*, page 7).

All of this competition translates into significant benefits for U.S. consumers. Today, U.S. mobile customers pay the lowest prices (on average $0.05 per MOU) and are by far the heaviest users of mobile telephony services among OECD countries.[19]

In summary, the continuous growth in subscribership leading to high rates of penetration, improvements in service quality and high levels of customer satisfaction,[20] breadth of service offerings, and indicia of fluctuating market shares and high rates of customer churn[21] all attest to a robustly competitive mobile services sector.

2.2. Mobile communications and the Internet

During the 1990s, in a parallel development, the Internet emerged as *the* platform for mass-market data communications. At the start of the decade, less than 1% of U.S. households subscribed to the Internet, whereas by 2000, almost 42% did.[22] In 1990, many folks had barely heard of the Internet, while a decade later, the Internet was being touted as the world's next growth engine.[23] The dot.com boom of the late 1990s promised an expanding world of on-line Business-to-Business (B2B) and Business-to-Consumer (B2C) electronic commerce. The promise was real, if a bit premature. The excessive exuberance that fueled the rapid appreciation in Internet-related equity valuations came crashing down in mid-2000 when investor confidence was shaken by the realization that making the transition to an Information economy would be more difficult than anticipated. The telecom downturn coupled to a worldwide recession resulted in a cascade of bankruptcies among many of the new businesses that had been launched to help

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[19] As of 1Q2009, U.S. subscribers were estimated to be using 830 MOU per month, almost twice the usage of the next highest OECD country (Canada at 420 MOU per month) (see Bank of America/Merrill Lynch, "Global Wireless Matrix 1Q09" Canada is the next highest in usage with 420 MOU per month.

[20] JD Powers survey data indicate that that call quality has been improving and customer satisfaction remains high (see, *2009 Wireless Call Quality Performance Study*, Vol. 2, J.D. Power and Associates, referenced at http://www.jdpower.com/telecom/articles/2009-Wireless-Call-Quality-Volume-2; and "J.D. Power and Associates Reports: Overall Wireless Carriers Reduce Dropped Calls, Failed Connections and Static, Driving an Improvement in Call Quality Performance," *J.D. Power and Associates Press Release*, August 27, 2009.

[21] Churn rates are around 22% per year (see page 45 of *Declaration of Michael Topper on behalf of Verizon Wireless*, In the Matter of Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993 Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless Including Commercial Mobile Services, Before the Federal Communications Commission, WT Docket No. 09-66.)

[22] According to the UN, 0.8% of U.S. citizens were Internet users in 1990 (see, *UN Human Development Report 2007/2008*, United Nations Development Program (2007), available at: http://hdr.undp.org/en/media/HDR_20072008_EN_Complete.pdf). According to the NTIA, 41.5% of households subscribed to the Internet in August 2000 (see, "A Nation On-Line: How Americans Are Expanding Their Use of the Internet," Department of Commerce, NTIA, February 2002).

[23] Business Week's cover heralded the "Internet Age" and had a lead article entitled "The Internet Economy: the World's Next Growth Engine," (see Business Week, October 4, 1999). A few issues later, the cover text referenced "The New Economy" and the lead article was entitled "The New Economy: It works in America, Will it Go Global?" (see Business Week, January 31, 2000).

deliver on the Internet promise. Nevertheless, and in spite of the downturn and resulting scaling back of Internet investments, Internet subscriptions and traffic continued to grow and electronic commerce expanded.[24]

2.3. Transition to a broadband Internet

One of the key challenges hampering Internet-driven growth was the slow speed of the last-mile access connections or "on ramps" to the Internet. The dial-up access used by most subscribers offered at most a 50Kbps connection and these connections were intermittent. While dial-up access proved adequate for text-based email and helped demonstrate the inherent value of on-line services and the World Wide Web (WWW), it was not adequate to support rich, interactive multimedia. Broadband access was required to unlock the potential of the Internet. The always-on connectivity and higher data rates offered by first generation broadband services (i.e., an order of magnitude faster, so 100s of Kbps) enabled a much higher quality Internet experience. Broadband makes it feasible to take advantage of rich media (video, voice) and Web 2.0-enabled interactivity, greatly expanding usability and the range of services and activities that may be undertaken on-line.

Cable television providers were the first to begin widespread deployment of broadband access services after 1996, benefiting from their earlier efforts to upgrade their cable networks in anticipation of providing more interactive television services and from earlier industry standardization of cable modem technologies. Telephone providers began widespread deployment of Digital Subscriber Line (DSL) broadband services somewhat later. As with other key Internet developments, once launched, progress was quick. In August 2000, only 4.4% of residential households had broadband (41.5% had Internet access); in October 2007, 50.8% of residential households had broadband (61.7% had Internet access).[25] Internet traffic continues to grow at the rate of 50-60% per year.[26]

Although the Internet and mobile telephony grew concurrently, it was not possible to tie the two services together using 2G mobile technologies. The effective data rates that 2G digital networks could support were too anemic (typically less than 10Kbps) to support useful wireless Internet access. In order for the broadband Internet and mobile communication services to converge, mobile networks needed to be upgraded to Third Generation, "3G," technologies.[27]

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[24] A recent report by Telegeography attests to the fact that Internet growth was robust during the most recent recession as well (see Telegeography (2009), "Global Internet Geography: Executive Summary," Report, September 2009 (available at: http://www.telegeography.com/products/gig/download/telegeography-global-internet.pdf).

[25] See Table 2.10 in *Trends in Telecommunications Services*, Federal Communications Commission, August 2008.

[26] See Minnesota Internet Traffic Studies (MINTS), http:///www.dtc.umn.edu/mints/home.html.

[27] The most common 3G technologies are the W-CDMA (HSDPA) technologies that are an upgrade of GSM (the most widely used 2G technology) and CDMA2000 (EVDO) technologies that are an upgrade of 2G CDMA.

2.4. Mobile broadband takes off

The first 3G services were launched in 2005 in the United States.[28] These services offered the ability to interconnect to the Internet over a mobile device at speeds that averaged from 50 Kbps (dial-up) to a few 100s of Kbps (i.e., approximating first generation fixed access broadband speeds).[29] Initially, these services were priced relatively high, targeted to those with a pressing need for mobile access (e.g., "road-warriors"). The predominant mode for accessing 3G Internet services was via data modem cards that plugged into laptop computers (rather than via mobile handsets that are the dominant device for most mobile telephony services).

At the same time that 3G services were being deployed, wireless local area networks (WLANs) based on the wireless Ethernet standard, Wi-Fi, began to take off. Wi-Fi was developed as a technology to exploit unlicensed spectrum in the 2.4GHz band to provide LAN connectivity over a local area (up to 100m) without requiring cabling.[30] Because of its limited reach and lack of support for voice telephony and high-speed mobility, Wi-Fi was not originally thought of as a mobile broadband technology. However, Wi-Fi proved extremely attractive in extending the reach of fixed broadband access services to allow more flexible access of broadband services within the home, and when deployed in public access points, as a way to provide "nomadic" Internet access either as a public service/economic stimulus effort (e.g., in government buildings, public libraries, or economic development zones), or for profit (e.g., via aggregators like Boingo[31] or iPass[32]). Moreover, because many private Wi-Fi access points are not secured, it is often possible for users willing to prospect for open access connections to connect to the Internet for free.[33] The proliferation of Wi-Fi demonstrated the potential for wireless to evolve along unexpected paths and pointed toward a broader understanding of the different ways in which "mobility" might be used and supported. In contrast to the mobile service provider 3G model, the growth of Wi-Fi was primarily driven by end-users purchasing and deploying Wi-Fi equipment to expand access options to fixed broadband services (provided via traditional wired cable or DSL modem services).

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[28] NTT DoCoMo launched the first commercial 3G service in 2001. Verizon Wireless launched the first commercial 3G service in the U.S. in February 2005, using its cdma2000 EV-DO network. Sprint and AT&T Wireless followed with competing offerings later that year.

[29] See for example, Figure 3 in "LTE: Future of Mobile Broadband Technology," Verizon Wireless White Paper, available at: https://www.lte.vzw.com/Portals/95/docs/LTE%20The%20Future%20of%20Mobile%20Broadband%20Technology.pdf

[30] The FCC approved unlicensed use in the 2.4 and 5.8 GHz ISM bands in 1985. The Ethernet LAN standards designed to exploit these, 802.11b (Wi-Fi) for 2.4GHz and 802.11a for 5.8GHz, were approved in 1999 and 2000, respectively.

[31] See http://www.boingo.com/.

[32] See http://www.ipass.com/.

[33] Because prospecting for an open connection incurs search costs and because the legality of using an open access point without permission is ambiguous, it is not true that such access is really "free."

The growth of Wi-Fi highlighted some of its deficiencies, including its lack of support for telephony, limited range, and support for managing shared access. This prompted the development of a new technology, WiMAX (IEEE 802.16), as a "Wi-Fi like" technology that was intentionally designed as a wireless "last mile" alternative to wired fixed broadband access. This enabled WiMAX to compete as a metropolitan area network (MAN) alternative to 3G, and with further standards development (IEEE 802.16e), it became a more potent competitor by adding better support for mobility and real-time services like telephony.[34] In contrast to 3G, the newer WiMAX technologies are perceived as more advanced, fourth generation or "4G" technologies that will offer much higher Internet access data rates (i.e., an order of magnitude faster data rates that are in the 10s or 100s of Mbps).

Meanwhile, the 3G providers and their vendors have continued to innovate and develop their own versions of much more capable 4G technologies. A growing number of 3G mobile operators have announced plans to migrate to a version of "4G" mobile technology that is referred to as Long Term Evolution or "LTE." Most of the largest U.S. mobile network operators (e.g., Verizon, AT&T, T Mobile, MetroPCS, Leap, US Cellular) have committed to LTE.[35] The peak data rates for 4G services are on the order of 50-100Mbps, although it is expected that the average throughput experienced by end-users will be closer to 5-12Mbps in the nearer term.[36] In addition to supporting an order of magnitude faster data rates, comparable to the experience of current wired fixed broadband services, the 4G LTE services are expected to provide a much closer to "always on" broadband experience because of the much lower latency involved in setting up a connection.[37]

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[34] For further information on WiMAX technology and standards see: IEEE 802.16 Working Group (http://grouper.ieee.org/groups/802/16/) ; or, the WiMAX forum (http://www.wimaxforum.org/).

[35] See "LTE Commitments," 3G Americas, March 2009 (available at: http://www.3gamericas.org/documents/LTE Commitments Mar 2009.pdf). Verizon Wireless will be the first with test deployments in Boston and Seattle in late 2009 (see "Verizon trialing LTE in Boston, Seattle this year," Brad Reed, Network World, 13 August 2009, available at: http://www.networkworld.com/news/2009/081309-verizon-trialing-lte-boston.html?ry=gs).

[36] As with other wireless technologies, the data rates supported depend on how the technology is deployed, how far the user is from the base station, how many other users are sharing the capacity, and which flavor of the technology is deployed. The peak rates that are theoretically possible (and often quoted in the trade press) are usually substantially higher than what is realized in practice; and peak rates realized in practice are significantly faster than the average throughput realized by users. The estimates of average data rates reported here are from "LTE: Future of Mobile Broadband Technology," Verizon Wireless White Paper available at: : https://www.lte.vzw.com/Portals/95/docs/LTE%20The%20Future%20of%20Mobile%20Broadband%20Technology.pdf.

[37] See Motorola (2007), "White Paper: Spectrum Analysis for Future LTE Deployments," 2007, available at: http://www.motorola.com/staticfiles/Business/Solutions/Industry Solutions/Service Providers/Wireless Operators/LTE/_Document/Static Files/LTE_Spectrum_Analysis_White_Paper_New.pdf.

As of 2008, 92% of U.S. citizens lived in a zip code with at least one mobile broadband provider[38] and 84% of US handsets were web-capable.[39] As of the first quarter of 2008, 40 million or almost 16% of mobile subscribers were regularly accessing the Internet using mobile broadband services.[40] Cisco forecasts that mobile data traffic will grow at 131% per year from 2008 through 2013, significantly faster than Internet traffic overall.[41] Wireless data revenues have been growing rapidly to about $27.5 billion in 2008, more than triple the $8.5 billion of data revenues in 2005.[42]

The investment and pace of innovation in mobile services generally, and mobile broadband especially, in the United States has been quite remarkable. As noted above, we have gone from 2G to initial deployment of 4G in less than a decade.

Although the growth we have seen in mobile broadband has been impressive, we are still in the early stages of the mobile broadband future. Previously growth was limited by a lack of infrastructure (and capacity), relatively high prices for mobile data service plans, and a lack of compelling user devices and mobile broadband applications. The introduction of the Apple iPhone in June 2007 represented a watershed change. Previously, most of the mobile broadband usage was due to subscribers using plug-in or internal data-modem cards with their portable computers. Even today, such data cards account for 34% of mobile data usage[43] and the usage by

[38] See *13th CMRS Report*.

[39] See CTIA (2009), "The Wireless Industry Overview," 21 August 2009 (available at: http://files.ctia.org/pdf/Wireless_Overview.pdf).

[40] According to Nielsen, as of May 2008 15.6% of mobile subscribers were regular users of the mobile Internet access and, 37% paid for access to mobile Internet services. These were the highest penetration rates observed in a panel of 16 countries (see "Critical Mass: the Worldwide State of the Mobile Web," Nielsen Mobile, July 2008).

[41] Internet traffic overall is projected to grow at 38%. Even though mobile data is projected to grow rapidly, it will still account for less than 4% of total IP traffic by 2013 (see Cisco (2009a), "Cisco Visual Networking Index: Forecast and Methodology, 2008 – 2013," 9 June 2009, available at: http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-481360.pdf).

[42] See CTIA—The Wireless Association (2009), "Wireless Quick Facts: Mid-Year Figures," available at: http://www.ctia.org/advocacy/research/index.cfm/AID/10323.

[43] See Cisco (2009b), "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update," 29 January 2009 (available at: http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html). The estimate is based on Cisco's forecast for handset and data card usage.

such users is significantly higher than for smartphone users.[44] However, the number of smartphones sold per year is much higher than the number of data cards.[45]

The iPhone represented a watershed in smartphone marketing. While smartphones like the Blackberry, Treo, and Palm had been available for a number of years, those phones were targeted toward professional users – the so-called road warriors. The iPhone was the first really successful smartphone to address mass-market consumers. Its interface (touch screen, ease-of-use menus), packaging (integration with MP3 music player, camera, Wi-Fi radio, and other consumer apps), and Apple branding struck a resonant chord with consumers. Since then mobile service providers have been scrambling to roll out a growing selection of new handsets to compete with the iPhone. At the same time, the traditional smartphone vendors have introduced enhanced models to address professional users and consumers, while Apple has upgraded its iPhone to make it more attractive to professional users with better email and calendaring functionality. In addition to including upgraded radios to connect to the newer 3G+ infrastructures, a growing number of smartphones are incorporating Wi-Fi connectivity as well as GPS location awareness capabilities.

The Wi-Fi connectivity is interesting because it allows users to connect to the Internet over Wi-Fi routers in their home (enhancing the value of fixed broadband services in the home) and via public access Wi-Fi points when away from home (thereby taking advantage of the potentially lower costs associated with Wi-Fi access – for example, where there is free Wi-Fi). Moreover, in many cases, Wi-Fi supports faster data rates than 3G services.[46]

The GPS capabilities enable true location-awareness and therefore support location-based services. These open up a whole new range of context-dependent Internet services that can be tailored to where a user is and what a user is doing. For example, identifying restaurants, gasoline stations, or hospitals that are close to the user. Integration with services like Google maps can provide real-time, location-specific directions. When coupled with various motion or other sensors (temperature, accelerometer), the location-awareness can help customize services

[44] According to ABI Research, the average data card user uses about 1GB/month, whereas the average 3G iPhone usage is about 500MB/month (see "Daily Edge: Rapid Growth in Mobile Broadband Traffic is Positive for Sandvine," Scotia Capital Equity Research, 17 August 2009).

[45] According to Scotia Capital, there were 140 million smartphones sold compared to 35 million data cards in 2008 (see "Daily Edge: Rapid Growth in Mobile Broadband Traffic is Positive for Sandvine," Scotia Capital Equity Research, 17 August 2009).

[46] Wi-Fi is based on the IEEE 802.11b wireless Ethernet standard that supports data rates up to 10Mbps, and newer standards support higher data rates. In contrast, most 3G services support lower peak data rates. The actual data rates that a user may experience will vary with the distance the user is from the base station, the quality of the wireless connection, and the level of network congestion. The typically higher data rate is easier to support with Wi-Fi because it is designed to operate over a shorter distance (which reduces power demands and spectrum sharing requirements). A number of operators offer handsets (e.g., AT&T's iPhone) that allow users to take opportunistic advantage of Wi-Fi when desired, while relying on 3G for ubiquitous area coverage.

to how fast or how the user is moving. Such capabilities are useful for enhancing the quality and interactivity of games or for health monitoring (e.g., detecting if the phone has fallen).

Apple's iTunes store (focused on the iPhone) and applications stores from other vendors (e.g., Blackberry, Handango, Palm, or Sony Ericsson) offer a plethora of free and for-fee applications to customize and enhance the capabilities of the new multi-featured smartphones.

At the same time that smartphones have been getting more capable and consumer choices have expanded, prices have fallen, making them even more attractive to mass market consumers. A few years ago, full-featured smartphones were selling for upwards of $400. Today, there are a number of models that are available to consumers for $100-$200.[47] Today, smartphones account for approximately 15% of handsets. One analyst forecasts that they will comprise 35% of handsets by 2013.[48]

The new generation of smartphones provide a glimpse of how we may use Internet-enabled appliances in the future. One analyst sees smartphones at the nexus of four previously discrete markets: (a) PCs & computing, (b) Internet, (c) Consumer electronics (cameras, game consoles, and music players), and (d) Mobile telephones. He argues that:

> "Smartphones offer improved ways to communicate and connect (email, instant messaging, social networking, multimedia messaging, etc.); browse and search the Internet with the richness of a desktop; entertain (music, movies, games, pictures, videos, etc.); interact and collaborate (blogs, MySpace, Twitter, Facebook, Flickr, etc.); organize life and work (calendar, contacts, notes, PIM, etc.); transact (search, browse, shop, buy, bank, etc.); find and guide (location-based applications, local search, directory services, mapping, etc.); stay informed (news, alerts, weather, traffic, etc.); mobilize the office (corporate email, corporate applications, private branch exchange (PBX) integration, mobile desktop, etc.) *and do thousands of things we haven't yet thought of or foreseen*."[49]

In addition to the growing usage of smartphones, we may expect to see continuing usage of data cards embedded in portable computers and the emerging class of ultra-portables, tablets and "netbooks". These latter devices are typically larger than a smartphone to allow a larger display and keyboard, but are designed to be less expensive, more power efficient, and/or more portable than more full-function portable computers.

Finally, there will be a growing class of niche products that are specialized for a particular class of application or usage context, and a growing class of devices to enable

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[47] Mobile operators typically provide a handset subsidy and require consumers who take advantage of the subsidy to sign term agreements of one or two years (see "Wireless emerging devices: Smartphones to drive data revenue," Macquarie Research Equities, 30 March 2009).

[48] See "Wireless emerging devices: Smartphones to drive data revenue," Macquarie Research Equities, 30 March 2009.

[49] See "Wireless Industry: the New World Order – Smartphones and Challengers to take Global Share," RBC Capital Markets Equity Research, 18 August 2009.

machine-to-machine (M2M) communications. The Kindle is an example of the former class of device. The Kindle, marketed by Amazon.com, is an electronic book reader that is optimized for displaying text that closely approximates the experience of paper print (high contrast, usability in varying light conditions, low power usage). The Kindle uses Sprint's 3G service to download electronic books. Examples of M2M devices may include devices to enable smart transportation or power grids, for example to support vehicle-to-vehicle communications or remote meter reading. The potential for other types of specialized or niche mobile Internet devices and M2M communications is immense. We are only in the very early stages of realizing this potential.

The proliferation of RFID and active sensor technology embedded in everything from goods in production to highways to the walls of our homes and offices will provide real time data on conditions and allow us to customize applications.[50] This will enable much richer and dynamic control algorithms that will be critical to improving energy efficiency. For example, sensor-enabled smart systems can help optimize the performance of engines, HVAC systems, and natural resource management practices (e.g., help manage forests or prospect for energy reserves). RFID tags on goods in production or transport facilitate better supply chain management. For example, a tag with an accelerometer attached to a flat panel display can tell if the display was dropped in transit and thereby allow the device to be identified as damaged without having to open the box. Such tags can be used to allow special handling instructions, including payment and other transaction relevant information to follow the tagged object. Such tags are used to track health records for domestic animals and may be used to enable better healthcare for humans as well. While many of these sensors may be wired or communicate using specialized narrowband or low power radios, it is likely that having so much potentially useful real-time and distributed information available around us will provide the basis for many new types of services and will help drive growth in Internet traffic volume, much of which will be from mobile broadband devices.

In this anticipated future, there will a wider spectrum of types of devices connected to the Internet. Originally, data communications were used to allow many users to share a single computer processor. Eventually, with the transition to personal computers, we reached a world of one processor per person. As the world of Internet connectivity becomes more pervasive and ubiquitous, we are moving toward a world in which there are many processors for each person. The Internet provides the basic fabric that ties all of these processors together to create the future of pervasive/ubiquitous computing in which anything and everything may be connected to the Internet. This is sometimes referred to as the *Internet of things*:

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[50] Radio Frequency Identification (RFID) tags may be encoded with a wealth of information and are readable by wireless devices (but are themselves, unpowered). Sensors are a wider class of similar devices that may have expanded functionality and are powered. RFID tags on goods in production enable per-item, real-time supply chain management; RFID tags/sensors on highways enable better traffic management and, in the future, may allow smart highways that can help control how vehicles drive; and, RFID/sensors in our homes and offices may enable smart homes which can adjust energy (lights, temperature) and provide enhanced security (monitoring) automatically.

"One major next step in this development is to progressively evolve from a network of interconnected computers to a network of interconnected objects, from books to cars, from electrical appliances to food, and thus create an 'Internet of things'"[51]

2.5. Mobility is the killer app

Today, we see a growing number of telephone users whose principal or only telephone service is mobile. As of 2008, slightly more than 20% of U.S. households' only telephone service was provided via a mobile phone.[52] Among college students and other younger demographics the share of "mobile-only" telephone subscribers is higher which suggests that the substitution of mobile telephony for fixed-line telephony will continue. There are a number of reasons for this, including the simple fact that the quality of mobile telephony has gotten much better while prices have fallen significantly. Today, there is a wide-range of voice plans that allow a large bundle of calls for a single flat rate anywhere in the United States under both pre-paid and post-paid payment models. As noted earlier, this is a consequence of the intense level of competition that is characteristic of mobile telephony services in the United States.

In addition to the positive developments of better quality and lower price, mobile telephony offers the very attractive feature that it supports *mobile* communications in its several dimensions. The compelling value of mobile communications helped drive rapid market growth in the early days, even when call-quality was much worse and service was more expensive than using a fixed line telephone at the time.

The first and most important feature of mobility is that it allows users to communicate wherever they are, whenever they want – enabling *always on, everywhere connected* communications. Mobility in this form expands the range of contexts in which a user may communicate. For example, calls may be made or answered when a fixed line phone is not available (e.g., when hiking in the woods or along the highway when your car breaks down). Mobility fundamentally enhances the value proposition of telephony service, making the service more valuable for all types of users (those with mobile phones who wish to make and receive calls, and those with fixed phones who want to communicate with mobile subscribers). The first mobile telephone services focused on allowing telephone conversations while driving along the highway. Given the amount of time Americans spend in their cars, the ability to communicate while on the road has proven quite attractive. From a network perspective, supporting lower speed mobility (e.g., at walking speeds) is technically even easier. Continuing innovation in radio systems made it feasible to design and operate much smaller, more power-efficient, and less expensive telephone handsets. The smaller handsets enabled personal portability. Instead of

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[51] See "Internet of Things – An Action Plan for Europe," Commission of the European Communities, 18 June 2009, COM(2009) 278, available at: http://ec.europa.eu/information_society/policy/rfid/documents/commiot2009.pdf.

[52] See Blumberg, Stephen and Julian Luke (2009), "Wireless Substitution: Early Release of Estimates From the National Health Interview Survey, July-December 2008," Division of Health Interview Statistics, National Center for Health Statistics, (available at: http://www.cdc.gov/nchs/data/nhis/earlyrelease/wireless200905.pdf).

having to be mounted in your car in a briefcase-sized box, the telephone could fit in your pocket and follow you anywhere.

This type of mobility is also very important for Internet access. Even setting aside Voice-over-IP (VoIP) telephony, much of what users use the Internet for is to communicate in a variety of modalities (instant messaging, email, multimedia conferencing). Enabling mobility for these Internet-powered communication modes enhances the value of the service by expanding the range of contexts in which communications may occur. Other Internet-based services like Web access, social networking, or electronic commerce are also enhanced through mobility.

Another dimension of mobility that is important is associated with flexible service deployment. With a fixed access connection, the user has to commit to a specific location and subsequent moves or changes are more complicated (and costly). For example, wireless services facilitate lower cost customer self-installs and self-configuring devices because wireless eliminates the problem of wiring the connection.[53] Of course, the flexibility benefits of wireless mobility are not limited to mobile broadband (e.g., fixed wireless broadband similarly benefits). The flexibility of wireless deployment is especially important for the future "Internet of Things," in which a much wider spectrum of diverse devices will need to be connected to the Internet.

A final dimension of mobility worth noting is "personalization." Mobile phones and mobile computing allow customization or personalization of devices and services. As the Internet becomes more pervasive in our social and economic lives, the range of environments, user-needs, and services that will be addressed will become more heterogeneous and diverse. When the only thing folks did with the telephone network was make "AT&T black phone" to "AT&T black phone" calls, the world of electronic communications was simpler to plan for. With the Internet, people and Internet-connected-devices may be doing multiple different things at the same time. Customization (enabled through mobility, location-awareness, device design, etc.) will help ensure the right service for the right situation. The personalization also will help with security and making the Internet more trustworthy which is becoming ever more important as we become more dependent on the Internet.

The world of pervasive/ubiquitous computing will both facilitate and have a greater need for customization. For example, M2M communications will allow automatic control of devices on our behalf in ways that often will not require human interaction (e.g., a smart car may brake automatically when the car in front brakes; a smart house may turn down the thermostat when no one is home or call a plumber if a pipe bursts; or a smart health monitoring system may dispense medications into a patient's bloodstream or call a doctor in response to real-time diagnostics). To make such systems secure and trustworthy, we will need a greater level of personalization to allow services and device behaviors to be context-sensitive (e.g., it may not be appropriate to administer a drug that makes one drowsy while one is driving).

As with flexibility, personalization powered by service mobility is not limited to wireless mobile devices. The interactivity, rich multimedia capabilities, and connectivity options of the

[53] This is not true for all wireless services, many of which may involve the placement of highly directional antennas.

Internet support diverse models for customizing communication, social, and commerce interactions. In marketing terms, it makes it possible to move from "mass marketing" to "one-to-one" marketing. Customers can get the content, goods, or services they want customized to the particular transaction, if desired. While wireless and mobile broadband are not essential to this, they make it much more likely. When one moves from a household computer with its broadband connection or the household fixed line phone to a smartphone with a broadband connection, the service comes closer to following the person, instead of following the device. In the future, because of M2M, networks will need to follow the person, the device, and the data/applications. In the "Internet of Things," everything may wish to talk to everything.

2.6. Implications for mobile broadband usage

The trends cited earlier point to continued growth in mobile data usage. The facilities-based mobile network operators are investing heavily to expand their service footprints and upgrade the quality of their networks to enable 4G powered services.[54] In response to falling prices and expanded choice and compelling user applications, smartphones are becoming an ever-larger share of the installed base of handsets. According to Cisco, each high-end smartphone today (e.g., an iPhone or Blackberry) has the potential to deliver 30 times the traffic of a typical basic feature handset; and each mobile data card has the potential to deliver 450 times as much traffic.[55] With the growth of M2M and other specialized devices like the Kindle or Internet-enabled video recorders, music players, or game stations, the number of broadband connected devices can go well beyond the number of broadband subscriptions. As noted earlier, Cisco has forecasted that mobile data will grow at 131% per year for the next five years, exceeding 2 Exabytes (or billion gigabytes) by 2013.[56]

Accommodating the growth in mobile device traffic will require substantial investment in mobile and fixed broadband infrastructures. The radio frequency spectrum is an increasingly scarce resource and meeting the demand for wireless services (which includes a much larger class of uses than mobile broadband) means that wireless technologies will have to become much more spectrally efficient. The new WiMAX and LTE technologies are expressly designed to make that feasible.[57] One way in which the capacity of radio systems can be expanded is through spatial reuse that entails using a larger number of smaller cell sites to cover a given area. With appropriate design, more of the radio frequency spectrum may be devoted to supporting users in any given area. These base stations will need to be interconnected to the backbone networks of

[54] Clearwire is already offering mobile WiMAX-based 4G services in a number of markets. Verizon wireless is expecting to launch commercial 4G LTE services in 2010 (see, "Verizon wireless announces 4G Venture Forum, designed to encourage innovation for advanced mobile networks," Verizon Wireless Press Release, 5 October 2009, available at: http://investor.verizon.com/news/view.aspx?NewsID=1011).

[55] See Cisco (2009b), note 43 *supra*.

[56] Ibid.

[57] For example, LTE is designed to be 2-4 times more spectrally efficient than 3G (HSPA) (see, Bogineni, Kalyani, Reiner Ludwig, Preben Mogensen, Vish Nandlall, Vojislav Vucetic, Byung Yi, and Zoran Zvonar (eds) (2009a), "LTE Part 1: Core Network," *IEEE Communications Magazine,* vol. 47, no. 2, February 2009).

the mobile providers, and ultimately to the rest of the Internet. To support the higher data rates enabled by 4G services and the growth in per-subscriber and aggregate traffic volumes per cell site will require denser deployment of fixed broadband infrastructures, including fiber optic cabling. In addition, providers are in the early stages of deployment of femtocell technology.[58] These are mini-cell sites that may be deployed inside buildings and homes to support mobile wireless access locally, while using a fixed broadband access service for back-haul.[59]

The growth of mobile broadband has the potential to help fuel significant economic growth. As with other types of ICT, there is growing evidence that the expansion of wireless services, including mobile broadband will contribute to GDP, productivity, and employment growth. One study estimated that wireless voice services added $157 billion in productivity gains and wireless data services added $28 billion in 2004 and 2005 respectively.[60] This same study forecasts that cumulative efficiencies from wireless broadband over the ten-year period from 2006 through 2016 will add $528 billion to in GDP productivity gains. The anticipated gains are expected from such productivity-enhancing improvements as better professional time management, improvements in healthcare efficiency, field service automation, improved inventory management to reduce inventory losses, and sales force automation. Another study projects that wireless broadband investment will add between 4.5 to 6.3 million jobs and 0.9% to 1.3% to GDP growth, or $126.3 to $184.1 billion.[61] Similar analyses for other countries are equally bullish.[62]

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[58] Sprint started offering femtocell services in 2008, and Verizon and AT&T rolled out their offerings in 2009.

[59] See Chandrasekhar, Vikram, Jeffrey Andrews, and Alan Gatherer (2008), "Femtocell Networks: A Survey," *IEEE Communications*, September 2008, 59-67.

[60] See Entner, Roger (2008), "The Increasingly Important Impact of Wireless Broadband Technology and Services on the U.S. Economy," A follow-up to the 2005 Ovum Report on the Impact of the US Wireless Telecom Industry on the US Economy prepared for the CTIA-Wireless Association, 2008 (available at: http://www.ctia.org/media/press/body.cfm/prid/1755).

[61] See Pearce, Alan and Michael Pagano (2009), "Accelerated Wireless Broadband Infrastructure Deployment: The Impact on GDP and Employment," *Media Law and Policy*, 18 (Spring 2009) 11-34.

[62] For example, CEBR (2008) estimated the mobile phones boosted labor productivity by 0.88% and GDP by 8.9 billion pounds in the UK in 2004 (see CEBR (2005), "'I Can't Imagine Working Without My Mobile' – An Analysis of How Mobile Phone Use Contributes to Business Productivity," report prepared by Centre for Economics and Business Research (CEBR) commissioned by O2, December 2005); Forge *et al.* (2007) estimated that the economic contribution from mobile at 208 billion Euros or 168 million Euros per MHz if the spectrum freed from the DTV conversion is mostly allocated to mobile services in Europe (see Forge, Simon, Colin Blackman, and Erik Bohlin, "The Mobile Provide: Economic Impacts of Alternative Uses of the Digital Dividend," a study commissioned by Deutsche Telekom/T-Mobile and prepared by SCF Associates, September 2007 (Available at: http://www.digitaldividend.eu/files/digital_dividend_summary_report.pdf); a 2007 Australian survey on the productivity of users of advanced (next-generation broadband) wireless services, found that there was an estimated average 9.3 percent increase in productivity from use of these services (see Econtech Pty Ltd. (2007), "Productivity Gains of Next G: Results on the Customer Survey," November 2007; and a 2008 Australian study estimated that GDP would be 1.65% higher by 2010 because of mobile (see Access Economics (2008), "Australian Mobile Telecommunications Industry: Economic Significance & State of the Industry" report by Access Economics Pty Limited for Australian Mobile Telecommunications

3. Implications for Fixed-Mobile Competition

In the mobile broadband future, the Internet and mobile communications services will finally be tied together. Mobile broadband will be used much more intensively on a wider array of device platforms and usage contexts to support a heterogeneous mix of applications and usage modes. Given the expectation that mobile services will continue to improve and the significant value added by mobility, it is worthwhile considering whether mobile broadband might replace fixed broadband Internet access altogether. In the following sub-sections, I will explain why I do not believe that is a reasonable expectation. Rather, I expect mobile and fixed broadband services to both advance, and remain distinct and valuable services that will be complementary. At the same time, I expect mobile broadband services to intensify competition, especially in the market for low usage and/or budget conscious broadband Internet customers and for lower quality earlier generation fixed broadband services.

3.1. Mobile and Fixed Broadband Differences Persist

As already noted, most users access the Internet via broadband connections provided over fixed location services via cable or DSL modem technologies.[63] The wired service terminates in the home to a modem that may be plugged into a router that allows multiple computers within the home to share the connection. The router may be bundled with or otherwise coupled to a Wi-Fi access point to support wireless (and hence mobile) access within range of the access point (i.e., a few hundred feet). That is usually sufficient to provide access within the home and its immediate vicinity (e.g., the backyard).

While it is true that mobile services are getting faster and service providers are expanding the range of services they offer, the same is true of fixed (mostly wired) broadband services. Both telephone and cable television companies have significantly upgraded the capacity and quality of their infrastructures to handle the rapidly growing Internet traffic. A key part of this effort has been the extension of fiber optic transmission technologies deeper into neighborhoods. Once installed, fiber optic transmission facilities provide the ability to dramatically scale capacity to meet most scenarios for future demand growth into the reasonably distant future. For this reason, many regard fiber optics as the only true "future proof" technology for last-mile infrastructure.

The largest incumbent telephone company, Verizon, has been investing heavily in FiOS, Verizon's fiber to the home (FTTH) service. By the end of 2009, Verizon expects FiOS to have an addressable market of 15 million homes. As of June 2009, Verizon had 3.1 million FiOS

Association, June 2008 (available at: http://www.amta.org.au/amta/site/amta/downloads/pdfs_2008/AE AMTA Final.pdf))

[63] There are also a number of providers that offer fixed broadband access services (often in rural areas that may be underserved by wired providers) in an analogous way, with WiMAX apparently emerging as the preferred technology. Many of these are smaller ISPs (e.g., Midcoast Internet Solutions which offers WiMAX-based services in Maine). Clearwire is perhaps the best-known provider of fixed wireless access services using WiMAX (although Clearwire also offers 4G mobile broadband services).

high-speed Internet customers taking advantage of services offering up to 50Mbps downstream data rates.[64] While not investing in broadband capacity as aggressively as Verizon, AT&T has been rolling out its U-verse product that provides second generation broadband service with peak download rates up to 18 Mbps.[65] The U-verse service is provided in most cases over fiber-to-the-node and then DSL over copper for the last couple of thousand feet to the home.[66]

Cable providers have similarly been upgrading their capacity with the latest flavor of technology known as DOCSIS 3.0. This supports broadband date rates on a par with current FiOS offerings. Analysts are predicting that more than 60% of cable modem customers will be able to benefit from DOCSIS 3.0 technology by the end of 2010.[67]

While the theoretical peak rates that may be supported over 4G LTE or WiMAX (50Mbps+) are comparable to the rates of the next generation fixed broadband services that the telephone and cable operators are currently deploying, mobile operators are not expected to be able to match those rates in the near future.[68] Meanwhile, fixed broadband services will continue to improve. Because of the inherent variability of wireless transmission and its reduced reliability as a transport layer compared to wired transmission and because of the inherent scarcity of radio frequency spectrum (e.g., all of the radio frequency spectrum could fit on a single fiber optic cable), it is likely that the peak and sustainable average data rates for mobile broadband services will continue to lag the data rates for fixed broadband services. The fundamental challenges and differences between supporting fixed versus mobile broadband services mean that mobile will likely continue to lag fixed services in terms of commercially available data rates.[69]

One might reasonably ask whether higher data rates are always preferable and whether there is not some threshold data rate beyond which further increases in speed would be

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[64] See "FiOS at Five: Continuing Rapid Growth, Leadership in Technology, and Innovation," Press Release, Verizon, 21 October 2009, available at: http://newscenter.verizon.com/press-releases/verizon/2009/fios-at-five-continuing.html.

[65] See "U-verse Update: 3Q09," AT&T Press Release, 22 October 2009, available at: http://www.att.com/Common/merger/files/pdf/3Q09_U-verseUpdate_10.22.pdf and http://www.att.com/u-verse/explore/internet-landing.jsp.

[66] The U-verse service binds several DSL channels together to expand the effective capacity that may be delivered to a customer's premises, allowing AT&T's U-verse offering to support multiple services (Internet, television, and voice) over an all IP platform and at higher rates than were possible over previous versions of DSL.

[67] See "U.S. DOCSIS 3.0: 20% today, 60+% 2010, 80% soon after," DSLPrime.com, October 2009, available at: http://www.dslprime.com/docsisreport/163-c/1428-us-docsis-30-20-today-60-2010-80soon-after.

[68] According to a Verizon white paper, the peak downstream (upstream) data rates for LTE ad WiMAX802.16e are 100Mbps (50 Mbps) and 46 Mbps (7Mbps), respectively; while the average user throughput is expected to be 5-12 Mbps (2-5Mbps) and 2-4Mbps (0.5-1.5Mbps), respectively (see "LTE: Future of Mobile Broadband Technology," Verizon Wireless White Paper, 2009).

[69] See Lehr, William and John Chapin (2009) "On the convergence of wired and wireless access network architectures," forthcoming in *Information Economics and Policy*, Winter 2010.

superfluous. If one were to believe this to be the case, then the inherent advantages of fixed over mobile infrastructures might be expected to become less important over time. While this might eventually be the case, it seems quite unlikely over the reasonably foreseeable future (say, next five to ten years). The technology forecasting landscape is littered with examples of premature predictions of how much computing or communications capacity would be needed that proved woefully inadequate. There are a number of reasons for why we should be cautious in prematurely predicting that per subscriber traffic growth will slow significantly. First, significant increases in capacity (e.g., order of magnitude increases) create the opportunity to support wholly new services that were not viable at the lower capacity levels. In the preceding section, I noted how the transition to a broadband Internet, and now, the emergence of true mobile broadband services offer a similar promise. Second, increased capabilities in one part of a system often encourage expanded demands from another. Consider how personal computer operating system and application software have expanded in size and resource requirements as the underlying hardware has become faster.

There are additional forces that will drive traffic demand over fixed broadband connections. For example, with fixed broadband access, multiple users within the home share the connection. As the number of personal computers and other types of Internet-connected devices in homes expand, the aggregate bandwidth that may be consumed by a household will also expand. Furthermore, the growth of M2M communications and the potential for faster-than-real-time delivery mean that the potential volume of traffic is not bounded by human time constraints.[70] Moreover, because a fixed broadband connection is likely to be shared among multiple users, its cost may be amortized over the multiple users. In contrast, mobile broadband subscriptions are typically per user (although there are discounted programs for families). When compared on a per user/per MB of data transferred basis, this means that mobile broadband services are typically more expensive. The relative cost disadvantage of mobile versus fixed broadband services is related to the underlying cost of spectrum capacity.[71]

In addition to the inherent capacity differences, the mobility that makes mobile broadband services so valuable also typically implies some additional constraints. Chief among these are power and form factor constraints. To be portable, mobile devices need to be small which limits screen size and the size of certain peripherals or input devices like keyboards. Powering mobile devices is also a challenge. The availability of portable power was one of the motivations for locating the first mobile telephones in vehicles, and the advances in battery technology proved critical in enabling the transition to smaller and more portable handsets.

[70] Thus, one is cautioned against trying to bound the volume of traffic an individual might consume or generate based on calculations of how many hours a day an individual might watch television, use the telephone, or browse the web. Significant volumes of traffic may be generated by M2M communications or in order to make content conditionally available where an individual may want it.

[71] Radio frequency spectrum is inherently scarcer than an equivalent amount of bandwidth on most wired infrastructures (see Lehr and Chapin (2009), note 69 *supra*). Obviously, there are usage contexts where this is not the case. For example, if the need for broadband data at a particular fixed location is temporary (e.g., fireman fighting a fire on the side of a remote mountain), then the total costs of provisioning fixed transmission resources would likely be significantly more than the cost of using a mobile service, even if the usage-sensitive fees for mobile data transport were higher.

While battery and power management technology have made significant improvements, mobile broadband enables us to do much more and doing so requires more power.

The form factor challenges of portability are also an issue. Watching high definition video on a small handset is unlikely to appeal to many. Of course, it is possible to connect peripheral devices to the portable handsets to allow access to larger screens or input/output devices, but such usage is not expected to be the dominant mode and the need to provision the additional peripherals makes mobility more cumbersome.

Finally, for many usage scenarios, mobility may not be valuable. For many, home Internet usage may occur predominantly in a few fixed locations within the home, and many of the rich media applications that drive bandwidth demand (e.g., video, interactive gaming) may be less viable if used while in motion. When mobility is less important, the other tradeoffs in terms of form factor, power, and pricing may be perceived to be relatively more burdensome.

In summary, while the quality of mobile broadband services will continue to improve and while mobility is a very valuable feature for many usage situations, mobility also imposes additional costs. And, the quality of fixed broadband is also improving so the relative quality differences remain. Whether mobile or fixed broadband is better will depend on the usage context.

3.2. Mobile complements fixed broadband access

Because it is likely that mobile broadband will lead to the creation of new Internet services and applications (e.g., mobile commerce, mobile healthcare, or location-aware services), it makes accessing the Internet more valuable for all Internet users (mobile and fixed). Expanding Internet use will also help generate scale and scope economies in Internet service provisioning (i.e., a larger market provides a larger base over which to spread the recovery of fixed costs). The extension of fixed applications to the mobile world (and visa versa) will expand the number of users and usage situations in which the application may be useful (e.g., a telephone call may be completed). This is the "network effect" that makes it more valuable for each member to subscribe to a larger network. Overall, these complementary effects should contribute to a rightward shift in aggregate demand and demand at most customer usage levels.

In addition to contributing to the value that existing broadband subscribers derive from Internet access, mobile broadband may make it easier to address the needs of under-served communities. Mobile broadband may be less expensive to deploy in certain situations (remote locations, temporary or ad hoc usage contexts). It is even conceivable that mobile broadband access may prove more valuable (than fixed access broadband) to some of the most disadvantaged in society like the homeless.[72] Because the Internet may assist in finding and keeping employment, enabling wider-spread mobile broadband access may complement other policies for promoting greater broadband access among underserved communities.

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[72] See Sullivan, Nicholas (2008), "Cell Phones Provide Significant Economic Gains for Low-Income American Households: A Review of Literature and Data from Two New Surveys," a report prepared for the New Millennium Research Council, April 2008 (available at: http://www.newmillenniumresearch.org/archive/Sullivan_Report_032608.pdf).

The growth in mobile Internet usage likely will add to aggregate Internet traffic. While it is certainly the case that mobile usage may substitute for fixed usage in certain cases (e.g., telephone calls made outside the home may replace telephone calls that would otherwise have been made using a fixed line telephone), the overall effect on aggregate Internet traffic is expected to be positive.[73] The growth of mobile broadband traffic will generate increased demand for backhaul transmission services for the larger number of smaller cell sites expected with 3G+/4G infrastructures. The demand for backhaul transport services will be met in many cases via the infrastructure (mostly fiber optic cabling) of fixed access providers. This will generate scale and scope economies for deploying additional fiber optic transmission infrastructure more deeply into neighborhoods, thereby lowering the long run incremental costs of providing fixed broadband access services. As with the deployment of femtocells noted earlier, the need to support backhaul from carrier base stations will provide another vector by which the growth of mobile broadband may complement the deployment of fixed broadband infrastructures.

Furthermore, although the architectures and capabilities of mobile and fixed networks are different, many of the inputs or components used to construct them are similar (e.g., storage technology, power supplies, network routers, etcetera) and so the growth of mobile infrastructure will contribute to learning, scale, and scope economies, and industry network effects that will contribute to lowering overall costs.

For many users, it is likely that mobile and fixed broadband services will be perceived as complementary. Just as the majority of households today have both fixed and mobile telephony subscriptions, we can expect that a significant share of households will continue to have both mobile and fixed broadband services into the future. While it seems reasonable that voice telephony might move predominantly to mobile platforms, the challenge of migrating broadband applications is greater. Voice telephony is a mature service that has become significantly commodified.[74] The benefits of mobility and the constraints imposed by form factor and power are less binding when it comes to voice telephony. When one considers multi-party video conferencing or other rich media applications, migration to a mobile platform seems inherently less compelling. Furthermore, the future for wireless technology seems likely to be more heterogeneous than may be the case for wired services, due in part, to fundamental technical differences between what it means to support a wired versus a wireless service.[75]

Taken together, these demand stimulus and cost-economy complementarities between fixed and mobile broadband services will contribute to making the overall broadband market opportunities larger. This is strongly pro-competitive since it has the effect of lowering entry barriers. Because the deployment of telecommunications infrastructure involves significant fixed and potentially sunk costs, there is a minimum efficient scale of operation (i.e., the size below

[73] See Cisco (2009), note 41 *supra.*

[74] Even with voice services there is room for further improvement with higher fidelity speech encoding and other services like teleconferencing.

[75] See Lehr, William and John Chapin (2009), "On the Convergence of Wired and Wireless Broadband Architectures," forthcoming in *Information Economics and Policy*, 2009.

which average costs rise sharply as market share falls). A smaller market means that fewer firms of minimum efficient scale may survive. A bigger market makes it feasible to support a greater number of firms, each of which may be competitive with a smaller share of the aggregate market.

3.3. Mobile and Fixed Broadband Substitution

Although I expect mobile and fixed broadband to operate more as complements, certainly over the medium term (next 3-5 years), there will be situations where it is reasonable to expect that the services will be perceived as substitutes (albeit, imperfect substitutes for all of the reasons cited earlier).

There will likely be some user groups and contexts where the value of having both a mobile and fixed service will be less compelling and where the availability of mobile broadband may cannibalize fixed broadband subscriptions.[76] Obviously, unless the prices of each service (or bundled offerings that include both) are sufficiently low, potential customers may be forced by budget considerations to choose one or the other service. Users who are more budget conscious (the young or others with limited incomes) are more likely to choose one instead of both services. Because usage pricing (costs) are likely to be higher for mobile broadband, heavy traffic users may prefer fixed broadband access, while light users (or those who live alone) may find the higher usage fees per MB of traffic transferred via a mobile service less burdensome. Users who place a high value on mobility are more likely to opt for mobile over fixed services when they make the choice. Conversely, those whose principal mode of usage is at a fixed location and who would find the form factor constraints of mobile devices especially binding (e.g., have a high need for a large sized display when using the Internet) may strictly prefer fixed broadband services. And, as mobile data rates increase, some users may find that for their usage profile, mobile is fast enough to meet their needs even for shared household use.[77]

The potential to substitute mobile broadband for fixed service (and visa versa) for some types of usage (e.g., make a telephone call from the car instead of waiting until you get home; or, print Google map directions before leaving the house rather than using your smartphone to get real time directions) will put mutual downward pressure on the pricing of each service.

The relative value of mobile over fixed services is greater when the fixed service is less capable. Thus, the performance of 4G services will be significantly more impressive when compared to a legacy DSL connection offering data rates of less than a few Mbps than if compared to FiOS or DOCSIS 3.0 cable modem services. Thus, the competitive discipline

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[76] There might be some potential customers who may subscribe to mobile broadband, but who never would have subscribed to (or used) fixed broadband services. To the extent that such subscribers exist, their usage of mobile broadband could not be viewed as cannibalizing fixed broadband demand.

[77] Although most mobile broadband use is not shared, there are devices available already that allow 3G services to be shared among multiple users. For example, CP technologies sells the "LevelOne MobileSpot" portable Wi-Fi router that allows a user to share his 3G data connection (see "CP Technologies Announces Always-On Wireless Connectivity With Its New Portable 3G Router," ThomasNet News, 29 April 2009, available at: http://news.thomasnet.com/fullstory/559820). Femtocell and other technologies may make it easier to share a mobile broadband service across multiple users in the future.

imposed by mobile broadband on fixed broadband services (and visa versa) will be stronger the greater the disparity in service qualities in a particular locale.

The competition between improving mobile broadband services and legacy fixed access broadband services provides a spur for fixed broadband providers to accelerate investment in upgrading their networks to differentiate their services along dimensions where it is relatively easy to do so. For example, it is relatively more difficult and expensive for mobile broadband providers to match the raw capacity of FTTH services and to offer higher volume caps (or unlimited data usage).

Although mobile and fixed broadband are not currently close substitutes, mobile services may still offer substantial competitive discipline for fixed broadband services. Even if only a relatively small percentage of subscribers contemplate replacing their fixed broadband connection with a mobile broadband service, this could offer enough competition at the margin to have a significant impact on the behavior of fixed broadband providers and the performance of fixed broadband service markets.

4. Conclusions and Public Policy Challenges

Overall, mobile broadband has the potential to deliver substantial benefits in market growth, expanded choice, and competition. By finally enabling the convergence of mobile communication services and the broadband Internet, mobile broadband can enable the creation of markets for wholly new services (e.g., mobile health, mobile television, machine-to-machine, etcetera), as well as enhancing the value of existing broadband services by allowing them to go mobile. This will increase aggregate demand for Internet services overall.

In addition, although their different strengths and weaknesses render them imperfect substitutes, mobile and fixed broadband will offer alternate solutions for accomplishing the same Internet goal (e.g., sending email, making a telephone call, or accessing the WWW) for some users and usage scenarios. Competition between these alternatives will provide a degree of market discipline across all broadband offerings that should contribute to lower pricing for consumers and enhanced incentives to invest in service upgrades to address additional demand. The emergence of 4G mobile broadband will offer a potent alternative to legacy DSL and cable modem services, but will not be likely to match the data rates and pricing expected from FTTH and DOCSIS 3.0 services that are already becoming widely available.

Taken together, this analysis suggests that the overall impact of mobile broadband will be strongly pro-competitive for broadband services overall, and for fixed broadband access in particular.

It is also worth noting that the significant progress we have seen in aggregate deployment of mobile broadband infrastructure attests to the robust competitiveness of mobile services markets. By virtually every metric, mobile services are today quite competitive.

From a policy perspective, the analysis included herein should make policymakers optimistic that the markets for broadband will remain competitive and that investment and innovation will continue to prosper as they have thus far. However, the technology and markets are evolving quite rapidly and the importance of broadband to society and the economy as basic infrastructure is growing. This means that continued vigilance to protect the health of the competitive process is warranted.

The obvious importance of mobile broadband for the future of the Internet means that any analysis of market power in broadband service markets will need to consider the impact of mobile broadband and the competitive dynamics between fixed and mobile broadband services. That impact is likely to be complex because mobile and fixed services will be complements, while also acting as imperfect substitutes for some components of demand. On the whole, I believe the evidence will support treating these a distinct and different – although clearly related – service markets. Quantifying the economic interactions between fixed and mobile services will be important if one anticipates adopting any regulatory interventions targeted at remedying any perceived deficit in broadband competition in either market. Because the market for mobile broadband is still relatively immature, estimating the requisite own-price and cross-price demand elasticities is difficult today and would be prone to relatively large uncertainty bounds. If we were to anticipate a significant problem for competition arising, then this would be worrisome. As the analysis presented here makes clear, however, the available evidence suggests that the impact of mobile broadband will be strongly pro-competitive. The rapid pace of progress in broadband-related investment (in infrastructure, in services, and in content and applications) and innovation all along the value chain (from services to content to applications to end-user devices) should give us pause before we consider imposing new regulatory obligations on broadband providers.

About the Author

Dr. William Lehr is an economist and research associate in the Computer Science and Artificial Intelligence Laboratory (CSAIL) at the Massachusetts Institute of Technology (MIT) and participant in the Communications Futures Program (CFP). The CFP is a joint industry-academic multidisciplinary research effort focused on the technical, economic, and public policy challenges confronting the Internet infrastructure industries. Dr. Lehr's research focuses on the economic and policy implications of broadband Internet access, next generation Internet architecture, and the evolution of wireless technology. In addition to his academic research, Dr. Lehr provides consultancy services on matters related to the information technology industries to public and private sector clients in the U.S. and abroad. Dr. Lehr has over twenty years of telecommunications industry experience as a researcher and industry consultant. Dr. Lehr holds a PhD in Economics from Stanford, an MBA in Finance from the Wharton School, and MSE, BA, and BS degrees from the University of Pennsylvania.