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THE NEXT BROADBAND CHALLENGE: WIRELESS

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Is fiber optics to virtually all homes a sensible policy goal? Perhaps not. At least, so argue Professors Middleton and Given, who suggest that, although wireless broadband may not be as fast as fiber, its adoption will be more rapid because it offers other attractive characteristics. Mobile broadband may have a disruptive effect on the overall broadband market, making fiber to the home less attractive. If this is so, should universal service obligations be extended to mobile broadband? And should governments rethink their plans for a ubiquitous fiber optic infrastructure? Middleton and Given argue that they should.

In June 2010, the President of the United States declared that "the next transformation in information technology" was beginning. He called it "the wireless broadband revolution." [1] National Economic Council Director Lawrence Summers called it "the third wave of the internet's development," placing the mix of public and private initiative needed to make the most of it alongside 19th century land grants for railways and educational institutions, as an example of the long American history of "government actions to assure the necessary foundational investments for economic growth."[2] The President announced that 500 MHz of spectrum would be made available for mobile and fixed wireless broadband over the next ten years and that research into spectrum sharing technologies would be strongly supported. In the 2011 State of the Union address, President Obama further reinforced the importance of "connecting every part of America to the digital age", by enabling businesses to deploy next generation wireless broadband services.[3]

This article explores the role of wireless technologies in providing broadband connectivity, and outlines challenges that arise in enabling wireless broadband development. It begins with a discussion of next generation broadband network initiatives, outlining the centrality of fiber

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[1] Barack Obama, *Presidential Memorandum: Unleashing the Wireless Broadband Revolution*, June 28, 2010, accessed Oct. 31, 2010, http://www.whitehouse.gov/the-press-office/presidential-memorandum-unleashing-wireless-broadband-revolution.
[2] Lawrence H. Summers, *Technological Opportunities, Job Creation, and Economic Growth*, Remarks at the New America Foundation on the President's Spectrum Initiative, June 28, 2010, accessed Oct. 31, 2010, http://www.whitehouse.gov/administration/eop/nec/speeches/technological-opportunities-job-creation-economic-growth.
[3] Barack Obama, Remarks by the President in State of Union Address, Jan. 25, 2011, accessed Jan. 26, 2011, http://www.whitehouse.gov/the-press-office/2011/01/25/remarks-president-state-union-address.

connectivity in current plans. It then makes the case that wireless broadband technologies may be disruptive, and have the potential to displace fiber as an essential future broadband technology. Recognizing the importance of wireless broadband, the paper then explores the role of wireless networking in a next generation broadband environment and articulates policy challenges arising from the promised "wireless broadband revolution" in the United States and elsewhere.

Broadband is widely viewed as an essential infrastructure for the 21st Century; thus governments believe that broadband network connectivity should be available to all.[4] The European Commission's Vice-President for the Digital Agenda, Neelie Kroes, says that "Fast broadband is digital oxygen, essential for Europe's prosperity and well-being."[5] Based on quantitative and qualitative evidence that adoption and use of broadband across an economy can result in strong economic benefits and improve quality of life for citizens,[6] many governments are making the development of affordable, reliable broadband infrastructure a national priority.[7]

Where there is a strong business case to be made for deploying next generation broadband, the private sector is generally willing to invest. In instances where a commercial return is less likely, the public sector is now often taking a role in encouraging broadband rollouts. Public sector involvement can range from creating a more favorable environment for private sector investment (e.g. changing the regulatory framework) and facilitating access to passive infrastructure,[8] to direct public investment (often through public-private partnerships)[9]. In addition to the motivation of providing affordable, high quality broadband access to everyone, public sector involvement often

[4] Broadband Commission for Digital Development, *A 2010 Leadership Imperative: The Future Built on Broadband* (New York: International Telecommunication Union and UNESCO, 2010), accessed Sept. 19, 2010, http://www.broadbandcommission.org/about.html; European Commission, *A Digital Agenda for Europe*, Brussels: European Commission, 2009, accessed July 28, 2010, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0245:FIN:EN:PDF; Federal Communications Commission. *Connecting America: The National Broadband Plan* (Mar. 16, 2010), accessed Mar. 16, 2010, http://download.broadband.gov/plan/national-broadband-plan.pdf.

[5] European Commission, *Digital Agenda: Broadband Speeds Increasing but Europe Must Do More*, Nov. 25, 2010, accessed Feb. 10, 2011, http://europa.eu/rapid/pressReleasesAction.do?reference=IP/10/1602&format=HTML&aged=0&language=EN&guiLanguage=en.

[6] Richard Hayes, "Valuing Broadband Benefits: A Selective Report on Issues and Options," accessed Feb. 1, 2011, http://broadband.unimelb.edu.au/resources/ValuingBroadbandBenefits.pdf; Christine Zhen-Wei Qiang, Carlo M. Rossotto, and Kaoru Kimura, "Economic Impacts of Broadband," in *Information and Communications for Development 2009: Extending Reach and Increasing Impact*, ed. World Bank (Washington, D.C.: World Bank, 2009); Tim Williams, "Connecting Communities: The Impact of Broadband on Communities in the UK and Its Implications for Australia," accessed Feb. 2, 2011, http://www.huawei.com.au/connectingcommunities/.

[7] The International Telecommunication Union reports that as of 2010, 82 countries were planning, or had implemented, a national broadband strategy. International Telecommunication Union, *ITU Statshot*, no.5 (Jan. 2011), accessed Feb. 8, 2011, http://www.itu.int/net/pressoffice/stats/2010/09/index.aspx.

[8] See for example European Commission, *Commission Recommendation of 20/09/2010 on regulated access to Next Generation Access Networks (NGA) {SEC(2010) 1037}*, accessed Sept. 20, 2010, http://ec.europa.eu/information_society/policy/ecomm/doc/library/recomm_guidelines/nga/document_travail.pdf.

[9] See for example the funding for broadband infrastructure provided through the American Recovery and Reinvestment Act of 2009; accessed Feb. 8, 2011, http://www.broadbandusa.gov.

has a second objective of changing the industry structure.[10] It is a common requirement that networks built with public funding be operated on an "open access" basis, meaning that all service providers can access the network under the same conditions. This removes the power of the network owner to discriminate against access seekers, creating a "level playing field" that should result in better outcomes for end customers (e.g. providing affordable services, offering more choice, and encouraging innovation).

Although regulation and practice are ostensibly governed by technological neutrality, many believe that the "end game" for next generation networks is deployment of fiber optical infrastructure. When extended directly to residential and business premises across nations, fiber is viewed as being "future-proof."[11] Because wireless networks cannot currently offer the same capacity as fiber networks, they are viewed as complements to fiber networks, rather than as viable next generation infrastructure in their own right.[12] Thus, the deployment of fiber directly to premises is central to many next generation network projects.[13] In Singapore, for instance, the Next Generation Nationwide Broadband Network is designed to provide fiber connections to individual premises at speeds of up to 1 gigabit per second (Gbps).[14] In Australia, the National Broadband Network will provide fiber connectivity to 93% of premises, with just 4% served by fixed wireless (and the most remote 3% served by satellite).[15] The European Commission states that "fibre is the next step in the natural technological evolution of the fixed-line telecommunications industry and essential to meeting the ambitious broadband targets set out in the Digital Agenda."[16]

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[10] For example, this is a stated objective of Australia's National Broadband Network initiative. Penny Wong and Stephen Conroy, *Statement of Expectations*, accessed Dec. 20, 2010, http://www.dbcde.gov.au/__data/assets/pdf_file/0003/132069/Statement_of_Expectations.pdf.

[11] R. P. Davey, D. Payne, P. Barker, K. Smith, M. Wilkinson, and P. Gunning, "Designing a 21st and 22nd Century Fiber Broadband Access Network," *BT Technology Journal* 25 (2007): 73-79; Government of Australia*, 21st Century Broadband*, 2009, accessed Sept. 10, 2010, http://www.dbcde.gov.au/__data/assets/word_doc/0017/112454/National_Broadband_Network_policy_brochure.doc; S. Derek Turner, *Down Payment on Our Digital Future. Stimulus Policies for the 21st Century* (Washington, D.C.: Free Press, 2008), accessed June 15, 2009, http://www.freepress.net/files/DownPayment_DigitalFuture.pdf.

[12] Rod S. Tucker, "Broadband Facts, Fiction and Urban Myths," *Telecommunications Journal of Australia* 60 (2010): 43.1-43.15.

[13] Singapore and Korea do have a wireless component in their national broadband strategies. Infocomm Development Authority of Singapore, *Fact Sheet: Wireless@SG*, accessed Sept. 1, 2010, http://www.ida.gov.sg/doc/News%20and%20Events/News_and_Events_Level2/20090728165354/WirelessSG_factsheet.pdf; Korean Communications Commission, *Beyond & More: Communications for a New Decade* (2010), accessed Sept. 11, 2010, http://www.convergencekorea.org/img/kiica_eng.pdf. The US National Broadband plan states as a long-term goal that "The United States should lead the world in mobile innovation, with the fastest and most extensive wireless networks of any nation." See Federal Communications Commission, *Connecting America: The National Broadband Plan* (2010), accessed Mar. 16, 2010, http://download.broadband.gov/plan/national-broadband-plan.pdf, xiv. Other projects will likely provide some wireless services, but ubiquitous wireless access is not currently a part of most next generation network plans.

[14] Infocomm Development Authority of Singapore, *What Is the Next Generation Nationwide Broadband Network (Next Gen NBN)?* accessed Sept. 1, 2010, http://www.ida.gov.sg/Infrastructure/20090717105113.aspx.

[15] NBN Co. Limited, "Corporate Plan 2011 – 2013," Dec. 20, 2010, accessed Dec. 20, 2010, http://www.nbnco.com.au/wps/wcm/connect/main/site-base/main-areas/publications-and-announcements/latest-announcements/nbn-co-corporate-plan-released.

[16] European Commission, *Broadband: Commission Sets out Common EU Approach on Ultra-Fast Broadband Networks*, 2010, accessed Sept. 20, 2010,

Fiber is viewed as the way of the future. Companies like Australia's NBN (responsible for building the national network) forecast exponential increases in network speeds,[17] thus supporting the case for investment in fiber connectivity. The rollout of fiber to the home, through commercial projects (e.g. telephone company investment in fiber in North America, including Verizon's FiOS initiative), municipal initiatives (e.g. Lafayette, LA; Chattanooga, TN), or flagship national projects like those in Singapore and Australia, appears unstoppable. There is no doubt there will be benefits realized from this wide scale fiber deployment. However, there are good reasons to question whether fiber is the only answer.

In the sections below we explore the possibility that wireless networks have been prematurely dismissed as viable future broadband infrastructure. The discussion begins with consideration of two assumptions embedded in next generation network projects. The first is that service delivery to the home is an essential component of next generation networking; the second is that services will require high capacity networks in order to provide end users with value. We suggest that neither assumption has yet been fully validated, and then make a case for wireless broadband being a disruptive technology. If it does prove to be a disruptive technology, wireless broadband will be the broadband infrastructure of choice for many citizens, and may well become more important than fiber broadband connectivity. As such, it is important to consider the policy environment for development of wireless broadband networks, and the implications of wireless networks playing a central role in delivering broadband services of the future. These issues are addressed in the final section of the paper.

NEXT GENERATION BROADBAND: DO WIRED AND WIRELESS NETWORKS COMPARE?

This section explores the stated rationales for building fiber networks to individuals' homes. It considers the possibility that wireless broadband infrastructure may do a better job of satisfying consumers' broadband needs in the future than fiber networks providing service to fixed locations like homes. This possibility is generally discounted on the basis that the delivery of broadband services over wireless networks is technologically inferior to delivery over fiber networks.[18] Wireless networks cannot match the capacity of fiber networks, and are less reliable than fiber.[19] Because network capacity is shared among users it is more difficult to provide multiple users with high

http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/10/424&format=HTML&aged=0&language=EN&guiLanguage=nl, 1.

[17] NBN Co. Limited.

[18] Ry Crozier, "Quigley: Why an all-wireless NBN is pointless," *ITNews*, Apr. 20, 2010, accessed Feb. 9, 2011, http://www.itnews.com.au/News/172614,quigley-why-an-all-wireless-nbn-is-pointless.aspx. See also Tucker.

[19] As Lehr and Chapin explain, the capacity limit of wireless networks is "a simple matter of physics" that cannot be resolved. William H. Lehr and John M. Chapin, "On the Convergence of Wired and Wireless Access Network Architectures," *Information Economics and Policy* 22 (2010): 34.

bandwidth connectivity using wireless networks.[20] Wireless broadband services are often more expensive than wired services, and may have lower data allowances.[21] These are all legitimate arguments, but they may prove to be irrelevant if users have different expectations for wireless broadband services than they do for wired services.

Wireless broadband networks can be built and operated using a variety of standards, providing differing functionality.[22] Support for mobile access is a feature of many wireless networks, but is not the essential distinguishing feature between fixed wireline services (those provided by DSL, cable or fiber to a single location) and wireless services. The focus of this article is on wireless broadband services that can be accessed outside the home, either by means of personal mobile broadband connections, or through fixed access points (e.g. hotspots or wireless zones) available to the public.[23] This discussion of wireless broadband does not include wireless networks installed inside homes to extend the reach of wired connections. It also excludes fixed wireless connections (often used to provide service to homes where it is uneconomical to provide wired broadband services) and satellite broadband connectivity.

Some argue that wireline and wireless broadband networks should be thought of as a single network, as there is common underlying infrastructure supporting wired and wireless connectivity. Wireless networks make use of wired (fiber) backhaul, and wireless technologies can be used to extend the reach of fiber networks. Wired and wireless networks are certainly complementary,[24] but from a consumer perspective the networks are not the same. Consumers may contract with different providers for wired and wireless services, and access the services using different devices (e.g. desktop computer for wired broadband, portable device for wireless). The networks offer different capabilities at different price points. As experienced by consumers, wired and wireless broadband services are different, despite common technical infrastructure that enables both networks and provides consumers with functional broadband connectivity. We explore and discuss these differences below.

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[20] OECD Directorate for Science Technology and Industry, *Developments in Fibre Technologies and Investment* (Paris: OECD Working Party on Communication Infrastructures and Services Policy, 2008), accessed Feb. 9, 2011, http://www.oecd.org/dataoecd/49/8/40390735.pdf.

[21] Yasuhiro Otsuka, *Mobile Broadband: Pricing and Services* (Paris: OECD Directorate for Science, Technology and Industry – Committee for Information, Computer and Communications Policy, 2009), accessed Feb. 9, 2011, http://www.oecd.org/dataoecd/26/19/43280727.pdf.

[22] For a discussion of the nature of wireless broadband services, see International Telecommunication Union, *The Portable Internet* (Geneva: ITU, 2004); N. Johnston and H. Aghvami, "Comparing WiMAX and HSPA – A Guide to the Technology," *BT Technology Journal* 25 (2007): 191-199; William H. Lehr and Lee W. McKnight, "Wireless Internet Access: 3G vs. WiFi?" *Telecommunications Policy* 27 (2003): 351-370; W. Lemstra and V. Hayes, "License-Exempt: Wi-Fi Complement to 3G," *Telematics and Informatics* 26 (2009): 227-239; Otsuka.

[23] For a discussion of the types of broadband connectivity available to individuals outside the home, see Catherine A. Middleton and Amelia Bryne, "An Exploration of User-Generated Wireless Broadband Infrastructures in Digital Cities," *Telematics & Informatics*, doi: 10.1016/j.tele.2010.08.003 (forthcoming).

[24] Navid Ghazisaidi, Martin Maier, and Chadi M Assi, "Fiber-wireless (FiWi) Access Networks: A Survey," *IEEE Communications Magazine* 47 (2009): 160-167.

Is Service to the Home Really Necessary?

Next generation network projects, like Australia's National Broadband Network and Singapore's Next Generation Nationwide Broadband Network, aim to bring broadband connectivity to individuals in their homes, providing access to a myriad of services delivered to personal computers or to other networked devices (e.g. telephones or televisions).[25] While these devices may be moved around inside the home, the services are delivered to a fixed location. Individuals cannot make use of fiber networks that are hard-wired into their homes from outside the home, potentially limiting the utility of such services.

Some services are well-suited to home delivery (e.g. interactive television, healthcare monitoring), and there will certainly be demand for services that can be accessed in the home. However, evidence from successful telehealth and e-learning projects (e.g. those offered using the SuperNet in Alberta, Canada[26]) also indicates that good service – making use of next generation networks – can be provided to individuals outside their homes. For instance, telehealth clinical consultations generally take place in a community medical facility, where the necessary equipment and expertise is available to facilitate the consultation. On the e-learning side, there is value in connecting schools to other schools and libraries and enhancing the learning environment in existing facilities where teachers can guide learning and staff can facilitate the technical aspects of connectivity. This is not to say that connections to the home would not create value, but experience to date indicates that instances of successful next generation broadband-enabled health and learning applications are frequently found outside the home.

Additionally, many individuals spend large portions of time away from home. Wireless service can be brought into the home, but a fixed, wireline service cannot be taken out of the home. Services delivered over wired broadband networks to in-home devices offer functionality not available with wireless services (e.g. watching a television show on a large screen TV is a different experience than watching the same show on a mobile handset). For some individuals however, the widespread availability of wireless services (especially anytime, anywhere mobile broadband services) far outweighs the added functionality available in services delivered to the home. Given that mobile devices allow increased access to services (offering far more flexibility than fixed devices), and that services supporting healthcare and education are being delivered successfully outside the home, it is worth questioning the assumption that the primary service delivery point for next generation broadband networks should be the home.

Is Fiber Really Needed to Deliver Services in the Home?

In North America in particular, where upwards of 90% of households pay for their television service to be delivered by satellite, cable or fiber (fiber to the home – FTTH, or fiber to the node – FTTN)

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[25] For further discussion of broadband service delivery, see Catherine A. Middleton, "Delivering Services over Next Generation Broadband Networks: Exploring Devices, Applications and Networks," *Telecommunications Journal of Australia* 60 (2010): 59.1-59.13.

[26] *The Alberta Supernet*, accessed Jan. 27, 2011, http://www.thealbertasupernet.com.

connection, TV is a driver of fiber rollouts.[27] There is intense competition between cable companies and telephone companies to lock households into service bundles, offering television, telephone (landline and/or mobile), and broadband services. Telcos cannot provide competitive television services without extending fiber closer to consumers' homes (e.g. Verizon's FiOS or ATT's U-Verse products), and have rolled out fiber in areas where they can generate a return by doing so (or at least stem the loss of customers to their cable rivals). As a result, in many urban areas across North America consumers will have a choice of either cable or telephone company fiber service to their homes (or close to their homes, with a FTTN offering), with no public investment needed to develop this infrastructure.

Elsewhere, public expenditure on fiber networks is justified because fiber is believed to be the only networking technology that can provide the high capacity connectivity needed for future services. Services identified as requiring very high bandwidth connectivity include advanced healthcare applications (e.g. remote monitoring and diagnostics), telepresence (very high resolution high definition videoconferencing), immersive gaming, cloud computing, and internet protocol television (IPTV).[28] Proponents of FTTH/FTTN argue that once fiber networks are available in homes, new applications will be developed that take advantage of their high capacity. To date however, the application that is most widely available is IPTV, and it is not clear when (or whether) other applications will achieve significant take-up.

Without bandwidth-hungry applications to drive demand for fiber connections, is there a need to provide fiber services directly to the home or can users make do with slower connections? Most of today's applications work well using existing DSL, cable, or wireless broadband connections. In many places where FTTH/FTTN or high speed cable broadband is available, very few people subscribe to the highest speed offerings, suggesting that there is not yet mainstream demand for such speeds.[29] On this point, it is noted that in Singapore and Australia, 50% to 60% of households offered connections to next generation broadband networks have taken up the offer. This figure does not indicate the percentage of households that have chosen to activate a next generation broadband service – rather it is the percentage of households who are allowing for this possibility by having the network connected to their homes.[30] Longer term, Australia's NBN Company predicts

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[27] This point is illustrated by Iain Marlow, "Telcos Make Assault on Cable's Stranglehold," *Globe and Mail*, Jan. 22, 2011, B4.

[28] For example, see California Broadband Task Force, *The State of Connectivity – Building Innovation through Broadband*, 2008, accessed Apr. 25, 2009, http://www.cio.ca.gov/broadband/pdf/CBTF_FINAL_Report.pdf; Stephen Ezell, Robert Atkinson, Daniel Castro, and George Ou, *The Need for Speed: The Importance of Next-Generation Broadband Networks* (Washington, D.C.: The Information Technology and Innovation Foundation, 2009), accessed Mar. 21, 2009, http://www.itif.org/files/2009-needforspeed.pdf; OECD Directorate for Science, Technology and Industry, *Network Developments in Support of Innovation and User Needs* (Paris: OECD Working Party on Communication Infrastructures and Services Policy, 2009), accessed May 5, 2010, http://www.oecd.org/officialdocuments/displaydocumentpdf/?cote=DSTI/ICCP/CISP%282009%292/FINAL&doclanguage=en.

[29] Ofcom, *International Communications Market Report*, 2010, accessed Dec. 2, 2010, http://stakeholders.ofcom.org.uk/binaries/research/cmr/753567/icmr/ICMR_2010.pdf.

[30] Stephen Conroy, *Commonwealth of Australia Parliamentary Debates. Senate Official Hansard. No. 6 2010. Tuesday, 15 June*, accessed Feb. 8, 2011, http://www.aph.gov.au/hansard/reps/dailys/dr130510.pdf.; Infocomm Development Authority

that in 2015 more than 50% of customers will opt for the lowest speed services (12 Mbps download speeds), with less than 15% opting for a 100 Mbps download service.[31]

There is a speculative aspect to the argument in favor of fiber networks: fiber is needed to support future applications, but few of these future applications actually exist. While it is certainly possible that future applications really will work best with fiber, it is also possible that applications and existing technologies may evolve in ways that will support users' needs without deploying fiber networks. Blind faith in a "build it and they will come" mantra is not sufficient justification for extending fiber networks to individual homes.

Is Wireless Broadband a Disruptive Technology?

The vision of fiber networks delivering bandwidth-intensive services to individuals in their homes builds on a tradition of wireline infrastructure. For many decades, landline telephones and cable television were mainstays in North American homes. Broadband, initially provided over a wired telephone line, and then through a wired cable or DSL connection, was the next step in the trajectory. Wired infrastructure offered reliability and familiarity. Over time various wired services were upgraded, offering new features and adding functionality, while retaining the security and comfort of a wired connection. Mobile phones were the first to challenge the supremacy of wireline infrastructure. As of June 2010, more than 25% of American households had "cut the cord" and were using only cell phones.[32] Now households are beginning to abandon cable television services in favor of over-the-air television ("new and improved" as a result of the digital television transition) and "over-the-top" video services (i.e. watching television on the internet; using services like hulu.com, NetFlix, iTunes, or network TV websites, or peer-to-peer file sharing).[33] Will fixed-line broadband networks be next?

The argument against wireless broadband as primary broadband infrastructure is that it can't do what fiber can do (because it is slower, more expensive, and less reliable). If next generation broadband networks are viewed as the next step on a wired infrastructure trajectory, then it is true that fiber will be better than wireless. But what if consumers are embarking on a new technological trajectory, one that favors access in many locations over fixed connectivity and that does not require the speed and reliability of fiber?

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of Singapore, *Chua Chu Kang Top Next Gen NBN Fibred-Up Constituency for 2010*, accessed Jan. 25, 2011, http://www.ida.gov.sg/News%20and%20Events/20100927182645.aspx?getPagetype=20#.

[31] NBN Co. Limited.

[32] Stephen J. Blumberg and Julian V. Luke, *Wireless Substitution: Early Release of Estimates from the National Health Interview Survey, January – June 2010* (National Center for Health Statistics, 2010), accessed Feb. 9, 2011, http://www.cdc.gov/nchs/data/nhis/earlyrelease/wireless201012.htm.

[33] Peter Kafka, "Hey Cable Guys! Cord Cutting Is Real, and It's a Problem, Says Verizon CEO," *All Things Digital*, Sept. 23, 2010, accessed Sept. 26, 2010, http://mediamemo.allthingsd.com/20100923/hey-cable-guys-cord-cutting-is-real-and-its-a-problem-says-verizon/.

The work of Bower and Christensen[34] is instructive here. They argue that companies that focus on the "next-generation performance needs" [35] of their customers fail to recognize innovative technologies. When innovation is understood as a trajectory that involves continuous improvement, the focus is on making existing technologies better by moving to the next generation of those same technologies. In the case of broadband, this can be seen in the framing of fiber connectivity as the "end game," better than DSL, cable, satellite, or wireless options. The broadband market has evolved by offering faster speeds and more reliable service. Fiber is the obvious next step in this evolution, as it will allow faster connections and improved reliability as compared to its precursors.

Bower and Christensen note that disruptive technologies "typically present a different package of performance attributes" that are not valued by existing mainstream customers.[36] In the case of fiber broadband, advocates for FTTH networks believe that fiber is essential for mainstream customers because of its superior performance attributes. Bower and Christensen also note that disruptive technologies often initially offer inferior performance on some dimensions, but are valued by new customers for their abilities to support new applications. For example, they describe how small disk drives were rejected by mainframe manufacturers for not offering sufficient storage capacity. However the smaller disk drivers were lightweight, inexpensive and were used in early personal computers. Personal computers were less powerful than mainframes, but offered attributes valued in the market. Size and cost became more valuable than storage space, and the personal computer gained market share at the expense of the technologically superior mainframe computer.[37]

Is the same true of wireless broadband? Is availability (access in many locations) more important than network performance? Does it matter that wireless networks are slower and less reliable than fiber ones? Will wireless broadband become the broadband access technology of choice for consumers despite its technical limitations?

What Do Broadband Users Want?

The above discussion identified some problematic assumptions underpinning the rollout of fiber networks: 1) they are designed to deliver services to individuals in their homes at a time when mobility and widespread network availability is becoming more valuable, and 2) they are designed to support a suite of bandwidth-hungry applications that either do not yet exist in any great numbers or that can be delivered outside the home. The discussion of disruptive technologies illustrates the real possibility that fiber, while technologically superior as a fixed-line broadband technology, may be superseded by a less powerful technology that enables new ways of accessing broadband services.[38]

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[34] Joseph L. Bower and Clayton M. Christensen, "Disruptive Technologies: Catching the Wave," *Harvard Business Review* 73 (1995): 43-53.
[35] Ibid., 44.
[36] Ibid.
[37] Ibid., 45.
[38] Wireless networks make use of fiber backbone connectivity. Our argument is not that fiber networks are unnecessary, but that the flexibility and availability offered by wireless networks can provide better value to users than higher speed, fixed fiber connections. This calls into question the wisdom of extending fiber to all homes as part of public broadband infrastructure projects.

Mobile broadband operators are investing heavily to improve network capacity, and will acquire additional spectrum as it becomes available to enable improved service. Although wireless broadband networks have had problems in serving large numbers of users,[39] Cisco reports that mobile data traffic has more than doubled each year for the past three years.[40] Broadband subscription data indicates increasing demand for wireless connectivity, supporting the idea that consumers value the attributes it offers despite the technical limitations. The OECD (Organization for Economic Co-operation and Development) reported on wireless broadband subscriptions for the first time in 2010, noting that there were well over 400 million wireless broadband subscriptions in OECD countries by June 2010.[41] This compares to almost 300 million fixed broadband subscriptions in the same period.[42] These data suggest that wireless broadband services are popular with OECD consumers. However, as fixed broadband subscriptions tend to serve households (with one or more users) and wireless subscriptions serve individuals, it should be noted that the fixed broadband services are likely serving more individuals than wireless broadband networks are.

In Australia, where telephone incumbent Telstra was aggressive in developing a 3G wireless broadband network, almost 40% of broadband subscriptions are for mobile wireless connections.[43] In Austria, which also has high mobile broadband take-up, the telecommunications regulator considers mobile broadband services to be a substitute for fixed line connections.[44] Not all mobile broadband subscriptions are being used as a primary connection,[45] but there is certainly demand for broadband connectivity outside the home. In addition to mobile broadband subscriptions (typically accessed using a USB "dongle" or a portable personal hotspot like a MiFi[46]), mobile broadband can be provided on a smart phone or a tablet device (users pay for a data plan to access this service).

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[39] See for example Jenna Wortham, "Customers Angered as iPhones Overload AT&T," *New York Times*, Sept. 3, 2009, B1.

[40] Cisco, *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2010–2015*, 2011, accessed Feb. 9, 2011, http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html.

[41] Wireless broadband includes data services for mobile phones, standalone broadband services as well as satellite and fixed wireless services. Organisation for Economic Co-operation and Development, *Broadband Portal - Press Release,* June 2010 data, accessed Feb. 10, 2011, http://www.oecd.org/document/4/0,3746,en_2649_33703_42800196_1_1_1_1,00.html.

[42] See Organisation for Economic Co-operation and Development, *Total Fixed and Wireless Broadband Subscriptions by Country*, June 2010, accessed Feb. 10, 2011, http://www.oecd.org/dataoecd/22/15/39574806.xls.

[43] Australian Bureau of Statistics, *Internet Activity, Australia, June 2010 - Internet Subscribers by Access Connection, for All ISPs*, Sept. 20, 2010, accessed Sept. 20, 2010, http://www.abs.gov.au/AUSSTATS/abs@.nsf/allprimarymainfeatures/6445F12663006B83CA256A150079564D?opendocument.

[44] European Commission, *Telecoms: Commission Endorses Amended Version of Austrian Broadband Access Market Definition*, 2009, accessed July 18, 2010, http://europa.eu/rapid/pressReleasesAction.do?reference=IP/09/1888&format=HTML&aged=0&language=EN&guiLanguage=en.

[45] Ry Crozier, "Optus Reveals Insight into Mobile Broadband Users," *ITNews*, Apr. 21, 2010, accessed Sept. 26, 2010, http://www.itnews.com.au/News/172700,optus-reveals-insight-into-mobile-broadband-user-base.aspx.

[46] For a description of the benefits of a personal mobile hotspot, see Kevin C. Tofel, "Is the MiFi Model the Future of Mobile Broadband?" *GigaOm*, Sept. 22, 2010, accessed Sept. 23, 2010, http://gigaom.com/2010/09/22/with-a-mifi-you-only-pay-an-isp-once/.

More than 35% of Australian internet users[47] and 38% of American internet users[48] reported that they had accessed the internet from a mobile device, and this service is popular in most OECD countries.[49]

A survey conducted for the Wi-Fi Alliance found that about 70% of American respondents (who were aged 17-29) spent at least four hours a day using a Wi-Fi broadband connection. More than 50% felt that Wi-Fi was a necessity in shopping areas and restaurants, with 87% saying they needed Wi-Fi at school or university.[50]

These data indicate that people are accessing broadband networks using three types of wireless connections: with Wi-Fi, with a mobile broadband device that provides connectivity to a computing device, or through a data service on a smart phone. Some individuals will use all three types of wireless broadband (possibly supplemented with a wired broadband subscription), and others will use just one or two. We are unaware of data that explore individuals' use of multiple broadband connections, but it seems clear that there is substantial demand for wireless connectivity in the mix.

Summary

The discussion above suggests that changing user behaviors (e.g. preference for mobility and access to services outside the home) and lack of demand for the speeds offered by fiber networks (in part due to limited availability of applications that require high bandwidth) raise questions about the immediate need for fiber broadband connectivity to individuals' homes. However, the belief that fiber is the next (and possibly final) step in the evolution of communications infrastructure is deeply held, and from this perspective, wireless broadband cannot compete with fiber. The history of disruptive technologies offers an alternative perspective, one that suggests that wireless broadband can not only compete with fiber networks in the short term, but that it may become the longer-term broadband solution of choice. In the following section, we outline the policy implications for the development of wireless broadband as a key component of national broadband infrastructures.

POLICY CONSIDERATIONS FOR THE WIRELESS BROADBAND REVOLUTION

From this point forward, we assume that wireless broadband connectivity will be an essential component of future broadband infrastructures. As noted earlier, most national broadband plans are currently focused on providing citizens with access to wireline infrastructure. Returning to our earlier discussion about the importance of broadband as a fundamental infrastructure of the 21st

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[47] Scott Ewing and Julian Thomas, *CCi Digital Futures 2010: The Internet in Australia* (Melbourne: ARC Centre of Excellence for Creative Industries and Innovation, Swinburne University of Technology, 2010), accessed Sept. 12, 2010, http://www.cci.edu.au/sites/default/files/sewing/CCi%20Digital%20Futures%202010%201.pdf, 2009 data.
[48] Aaron Smith, *Mobile Access 2010* (Washington, DC: Pew Internet Project, 2010), accessed July 20, 2010, http://pewinternet.org/~/media//Files/Reports/2010/PIP_Mobile_Access_2010.pdf (2010 data).
[49] Organisation for Economic Co-operation and Development, *Total Fixed and Wireless Broadband Subscriptions by Country*.
[50] Wi-Fi Alliance*, Wi-Fi Technology Is Now Central to How We Connect and Bond with Family and Friends*, 2010, accessed Sept. 23, 2010, http://www.wi-fi.org/news_articles.php?f=media_news&news_id=999.

Century, we outline policy issues that arise when wireless broadband becomes central to the provision of this fundamental infrastructure. There are more questions than answers at this point.

Should Universal Service Obligations Extend to Wireless Broadband?

The Broadband Commission for Digital Development calls for "broadband inclusion for all," but does not offer specific recommendations about how to achieve this objective.[51] The European Commission also calls for "broadband for all," with a target date of 2013.[52] Differing policy environments will call for different approaches to providing universal access to broadband networks. One policy approach that has received some attention is the universal service obligation (USO). Without going into detail on the history of the concept, the basic idea is that universal access to an essential service can be enabled with specific policy directives.[53]

Basic telephone services have been subject to USOs for many years. Access to dial-up internet is included in some USOs.[54] Finland has already enacted a universal service policy for broadband, requiring that (as a minimum) every permanent residence and business have access to a 1 Mbps connection.[55] The extension of USOs to broadband services is now on the agenda elsewhere as well. For instance, the European Commission is currently reviewing information gathered in a public consultation process about EU universal service guidelines. As this article was going to press, the FCC in the US announced a rulemaking (consultation) process to extend the universal service fund to support the provision of wired and wireless broadband services.[56] The ITU reports that more than forty countries now include broadband in their universal service policies.[57]

National broadband projects that are building FTTH will enable broadband for all (whether individuals and households choose to use broadband services is another matter). The rollout of fiber will take some time however, and with increased demand for wireless connectivity, there is a question as to whether wireless broadband service should be included in USO policies. By default, a universal service obligation to extend broadband connectivity to all citizens includes wireless

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[51] Broadband Commission for Digital Development, *A 2010 Leadership Imperative: The Future Built on Broadband* (New York: International Telecommunication Union and UNESCO, 2010), accessed Sept. 19, 2010, http://www.broadbandcommission.org/about.html.
[52] European Commission, *A Digital Agenda for Europe* (Brussels: European Commission, 2009), accessed July 28, 2010, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0245:FIN:EN:PDF.
[53] For an overview, see Jock Given, "The Eclipse of the Universal Service Obligation: Taking Broadband to Australians," *Info* 10 (2008): 92-106.
[54] See for example Canadian Radio-television and Telecommunications Commission, *Telecom Decision CRTC 99-16*, 1999, accessed Sept. 23, 2010, http://www.crtc.gc.ca/eng/archive/1999/dt99-16.htm; Neelie Kroes, *Who Pays What? Broadband for All and the Future of Universal Service Obligations*, Address at Nordic Broadband Forum, Copenhagen, Sept. 15, 2010, accessed Sept. 18, 2010, http://europa.eu/rapid/pressReleasesAction.do?reference=SPEECH/10/434&format=PDF&aged=0&language=EN&guiLanguage=en.
[55] Ministry of Transport and Communications, *Access to a Minimum of 1 Mbit Internet Connection Available to Everyone in Finland by July 2010*, Oct. 16, 2009, accessed Sept. 25, 2010, http://www.lvm.fi/web/en/pressreleases/view/920100.
[56] Federal Communications Commission, *FCC Proposes Modernizing and Streamlining Universal Service*, 2011, accessed Feb. 10, 2011, http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-304522A1.pdf.
[57] International Telecommunication Union, *ITU Statshot*, no. 5, Jan. 2011, accessed Feb. 8, 2011, http://www.itu.int/net/pressoffice/stats/2011/01/index.aspx.

broadband connectivity (i.e. any technology can be used to provide service). The real question then is whether specific provisions should be included to require that all citizens have access to wireless broadband connectivity – that is, connectivity that supports access from multiple locations.

This is a complex question, and requires consideration of both the principle and of the mechanisms required to enact it if it were deemed to be a desirable approach. It also requires some understanding of the current wireless broadband market. One option is to develop national wireless broadband infrastructures as an extension of planned FTTH networks.[58] Such networks could be operated on an open access basis (this point is considered more fully below), with the objective of providing affordable, high quality service using wireless, just as would be done using fiber. It is noted that in many developed countries private sector mobile broadband providers already provide near-ubiquitous wireless coverage, raising the question of whether these providers could or should be mandated to extend service to all in a manner consistent with a USO (e.g. ensuring that the service is affordable). If so, should spectrum be allocated to providers to enable them to deliver services as part of a USO?

Should Wireless Broadband Be Public Infrastructure?

To date most wireless broadband connectivity is provided by the private sector, and is not typically subject to the same open access regulation as wireline broadband networks (e.g. copper local loop unbundling, third party internet access for cable networks).[59] While the fiber networks being built as national infrastructure are not public infrastructure per se, they will be operated on an open access basis with the objective of allowing any service provider access to any customer, with no restrictions on the nature of the service.[60] It is assumed that wireless networks built on top of (or perhaps in lieu of) national fiber networks would operate on the same principles. This is the case for the segment of the Australian National Broadband Network that will be based on fixed wireless technologies.

Existing wireless broadband networks operated by private sector operators do not offer open access to their networks. In the case of wireless broadband services accessed by smart phones, not only are the networks closed to various content providers (taking a "walled garden" approach that restricts what consumers can access), users can be restricted from connecting their devices of choice to particular networks.[61] Handset manufacturers and carriers may disable functionality on specific devices (e.g. disallowing use of Wi-Fi to force customers to pay for access to data through a carrier's

[58] Such an undertaking is not trivial, and would require significant investment in equipment, extensive fiber capacity in the backbone, as well as adequate spectrum.

[59] For a discussion of open access regulation and its impacts, see Yochai Benkler, Robert Faris, Urs Gasser, Laura Miyakawa, and Stephen Schultze, *Next Generation Connectivity: A Review of Broadband Internet Transitions and Policy from Around the World*, accessed Feb. 10, 2011, http://cyber.law.harvard.edu/sites/cyber.law.harvard.edu/files/Berkman_Center_Broadband_Final_Report_15Feb2010.pdf.

[60] Catherine A. Middleton and Jock Given, "Open Access Broadband Networks in Australia, Canada, New Zealand and Singapore" (paper presented at the Telecommunications Policy Research Conference. Arlington, VA, Oct. 2010.)

[61] Rob Frieden, "Wireless Carterfone – A Long Overdue Policy Promoting Consumer Choice and Competition" (Working Paper #20, Washington, DC: New America Foundation, 2008), accessed Apr. 2, 2010, http://www.newamerica.net/files/nafmigration/Wireless_Carterfone_Frieden.pdf.

own 3G network), or restrict the use of applications (e.g. Skype was initially not enabled for use on AT&T's 3G network in the US).

Google and Verizon's "joint policy proposal for an open internet" specifically excludes wireless networks, arguing that the "still nascent" nature of the mobile marketplace merits a different approach.[62] Some observers[63] suggest that this exemption was designed to allow companies like YouTube (owned by Google) to negotiate directly with carriers to offer special deals for delivering their content over the mobile internet. In Canada (and elsewhere), carriers are buying content creators (e.g. Bell's purchase – for the second time – of television network CTV[64]), and making exclusive arrangements for content provision (e.g. NFL football games are only available on the Bell network in Canada[65]).

As private sector companies, mobile operators' wireless broadband offerings are designed to provide a return to investors. While meeting their customers' needs should be paramount, mobile operators currently have a lot of power in the market and are able to impose conditions on their customers' use of mobile broadband networks that reduce the customers' abilities to use the network in ways that they choose. If wireless broadband networks are considered essential infrastructure, is it appropriate that mobile operators have such control over these networks and how they are used? Budde observes that "spectrum is nothing more than infrastructure and, as we have seen in the fixed network, if infrastructure becomes monopolised some serious issues arise regarding the use of it."[66] Should the principles guiding public sector investment in fiber networks be applied to wireless networks (regardless of who is operating them), to ensure that there is a level playing field, and that services are affordable and of high quality? Or should these principles only apply to wireless networks that are developed with public sector investment? What does it really mean to incorporate wireless broadband networks into national broadband plans, and how can the public's interest best be served?

Should national governments continue to invest in fiber networks?

This is a provocative question. As noted earlier, fiber investments are probably unstoppable. Additionally, there is certainly good reason to invest in fiber backbone capacity, as it can support FTTH and wireless networks. Telephone and cable companies have been extending fiber closer to consumers' homes for years, and are unlikely to stop doing so, especially in environments where there is strong competition between the two. The real question of interest here is whether public

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[62] Google and Verizon, *A Joint Policy Proposal for an Open Internet*, 2010, accessed Sept. 25, 2010, http://googlepublicpolicy.blogspot.com/2010/08/joint-policy-proposal-for-open-internet.html. The proposal by Google and Verizon has been largely adopted as official policy by the FCC.

[63] For example, see Ryan Lawler, "YouTube to Mobile Operators: Partner up with Us," *GigaOm*, Sept. 24, 2010, accessed Sept. 27, 2010, http://newteevee.com/2010/09/24/youtube-to-mobile-operators-partner-up-or-else/.

[64] Bell Canada Enterprises, *Bell to Acquire 100% of Canada's No.1 Media Company CTV*, Sept. 10, 2010, accessed Sept. 25, 2010, http://www.bce.ca/en/news/releases/corp/2010/09/10/75551.html.

[65] Bell Canada Enterprises, *Bell Mobility Scores Touchdown with Exclusive NFL Partnership*, Sept. 8, 2010, accessed Sept. 25, 2010, http://www.bce.ca/en/news/releases/bm/2010/09/08/75547.html.

[66] Paul Budde and Kylie Wansink, *Global – Key Telecoms, Mobile and Broadband Statistics* (Bucketty, NSW: BuddeComm, 2010), 56.

sector investment in building fiber networks should continue, or whether this investment should be reconsidered in light of increasing demand for mobility, and current lack of applications requiring fiber's high capacity.

Williamson argues that a combination of 3G, LTE, and copper infrastructure will serve the needs of many consumers for the foreseeable future.[67] Many consumers use Wi-Fi to distribute their broadband signals within their homes now, rather than using an in-home wired network. As such, rather than bringing fiber directly to each premise, would it be effective to pair a fiber to the node (FTTN) infrastructure with a "last 100 meters" wireless connection? This would save the cost of bringing fiber to the home, and in the many locations where fiber already extends deep into the customer access network could be implemented very quickly. The end user experience would not be significantly different than if the FTTH signal were distributed with in-home Wi-Fi, but the cost and build time would be decreased.

It seems likely that the short- to medium-term broadband needs of most urban households could be met by upgrading the existing copper and cable infrastructure, rather than immediately building fiber to the home. As the FCC notes (referring to the US broadband market), "While end-users are likely to demand more speed over time, the evolution of that demand is uncertain. Given current trends, building a future-proof network immediately is likely more expensive than paying for future upgrades."[68] If wireless broadband does prove to be a truly disruptive technology, there may never be a compelling case for extending fiber to the majority of homes across a nation.

The US as a Mobile Broadband Leader, and Learning from Other Jurisdictions

The broadband policy environment differs from country to country. There are however many fundamental principles that are common across nations (especially within the OECD), and it is not unusual for policy that is initiated in one jurisdiction to be taken up in another. In the case of wireless broadband policy, domestic US decisions are likely to be internationally significant. Just as the shutdown of analog television in June 2009 and the allocation of vacated spectrum for wireless broadband has spurred global device manufacturers, equipment suppliers, and service providers to develop new products, services, and business models for international as well as American markets, US spectrum decisions and consumer experiences seem likely to influence options, thinking, and choices in other countries. For instance, the FCC's 2010 decision to allow use of vacant TV spectrum (white spaces) for provision of wireless broadband[69] was much anticipated, and may influence similar actions in other countries. President Obama's early 2011 announcement of a "Wireless Innovation and Infrastructure Initiative" to provide 98% of Americans with access to high

[67] Brian Williamson, "Nomadicity and the Evolution of Applications, Networks and Policy," *Telecommunications Journal of Australia* 60 (2010): 62.1-62.11.
[68] Federal Communications Commission, *The Broadband Availability Gap – OBI Technical Paper No. 1*, 2010, accessed Aug. 18, 2010, http://download.broadband.gov/plan/fcc-omnibus-broadband-initiative-(obi)-technical-paper-broadband-performance.pdf, 3.
[69] Federal Communications Commission, *FCC Frees up Vacant TV Airwaves for "Super Wi-Fi" Technologies*, Sept. 23, 2010, accessed Sept. 23, 2010, http://www.fcc.gov/Daily_Releases/Daily_Business/2010/db0923/DOC-301650A1.pdf.

speed wireless broadband[70] was immediately noted around the world, with calls for similar wireless infrastructure to be made available in other countries.[71] The evolution of network neutrality policies in the United States, particularly with respect to wireless networks, will also be of interest.

Equally, international actions will shape the US market. For example, evidence of improved wireless broadband coverage, take-up, speeds, prices, and usage in international markets seems likely to spur competition among national governments anxious to be perceived as mobile broadband leaders, just as has occurred with fixed line broadband services. The US is not currently the leader in mobile broadband connectivity, lagging behind many other countries where both mobile data plans (for smart phones and tablets) and standalone mobile broadband services are cheaper, faster and more widely used. What sorts of policies have resulted in better connectivity and pricing outside the US? Could these be adapted to the US market, in order to provide users with better broadband infrastructure? There are many policy questions to be answered, and exploring them in an international context can provide some useful insights.

CONCLUSION

This article has explored the role of wireless broadband networks as part of next generation national broadband infrastructures. It concludes that although wireless networks are not a direct substitute for wireline broadband connections, wireless networks may have a disruptive effect in the broadband market. This conclusion draws into question the wisdom of continued investment in fiber to the home connectivity, suggesting that a combination of upgraded existing infrastructure (e.g. FTTN/VDSL and cable DOCSIS 3.0 connectivity) plus universal wireless access may better suit individuals' needs.

If wireless is to take a more central role in the broadband ecosystem, it is important to consider the conditions under which it is provisioned. Wireless operators are not currently subject to open access requirements, and as such are able to impose restrictions on the ways that their networks are used. If broadband networks are essential infrastructure, then wireless connectivity should be provided according to the same principles as fiber connectivity, in order to ensure public benefit. As such, decisions about universal service obligations for broadband networks should consider whether access to wireless networks should be required for everyone. Finally, it is recognized that policy decisions in one jurisdiction (e.g. the US) may influence the regulatory environment in other countries, and policy makers should keep themselves informed of international developments.

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[70] Office of the Press Secretary, *President Obama Details Plan to Win the Future through Expanded Wireless Access*, Feb. 10, 2011, accessed Feb. 10, 2011, http://www.whitehouse.gov/the-press-office/2011/02/10/president-obama-details-plan-win-future-through-expanded-wireless-access.

[71] Indeed, there were calls to emulate this approach before the initiative was officially announced. See for example Mitchell Bingemann, "A Smarter Way to Get All Connected," *The Australian*, Feb. 8, 2011, 11; Jeffrey A. Eisenach, "Follow Obama's Lead on Wireless," *The Australian*, Feb. 7, 2011, 14.

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