TECHNOLOGIES AND POLICIES TO CONNECT THE NEXT FIVE BILLION

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ABSTRACT

In this Article, we present a broadband deployment framework describing how "the next five billion" may be connected to the Internet in the future. This framework identifies the most promising Internet technologies and the areas where they should be deployed. To summarize, we see wireless platforms being used in rural markets and other areas that will benefit greatly from a high degree of shared infrastructure, particularly with an electrical powering solution. Over time, fiber-based networks will gradually fill across the network, migrating from the core to the edge.

In our research, we also describe and promote a certain set of policies (many of which may not require laws) that will facilitate the prompt and efficient deployment of broadband infrastructure. These policies include (1) promoting shared infrastructure, (2) liberalizing spectrum policy, (3) facilitating access and interconnection through Internet exchange points, (4) creating an ecosystem that stimulates demand for broadband (and associated innovation, entrepreneurship, and technical experimentation), and (5) sharing information and discussing best practices among parties with common interests within geographical regions.

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I. INTRODUCTION

Despite the fact that the Internet has reached almost full deployment in developed countries, the numbers of people in the world who are not connected to the Internet outnumber those who are. Because the Internet has social and economic value and helps to flatten the inequalities posed by this "digital divide," the world's policymakers and regulators increasingly focus on questions regarding how to connect all people to the Internet. From the perspective of cost or complexity, the most difficult problem to solve in this endeavor is how to extend the Internet over the "last mile," or the network segment that extends from a hub on the metropolitan area network to the location of the individual user.[1] Commentators regularly use the term last mile and recognize the importance of this segment of the network, which brings the connection directly to the customer.[2] Yet despite of the frequency of the term's usage, our research reveals a significant gap in recent literature addressing this focus in a way that is easily accessible to regulators, policymakers, and entrepreneurs.

In this Article, we present suggestions for connecting "the next five billion" people to the Internet over time using a broadband deployment framework. This framework identifies the most promising technologies and the areas where they should be deployed, along with the best policy approaches to facilitate prompt and efficient deployment. No single technology can address all coverage and bandwidth concerns. Rather, different kinds of technologies for the last mile of broadband infrastructure will be required to connect these users.

The last-mile network is perhaps the most challenging segment to be addressed because of the high cost of deployment and significant policy hurdles.[3] While we provide specific and concrete advice that attempts to

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1. *See infra* Figure 1.

2. *See, e.g.*, James B. Speta, *Handicapping the Race for the Last Mile?: A Critique of Open Access Rules for Broadband Platforms,* 17 YALE J. ON REG. 39, 41, 45, 62–63 (2000) (describing the importance of the last mile in various contexts and how interconnection rules have been put in place to assure access to customers within the last mile); *see also The Battle for the Last Mile*, ECONOMIST, Apr. 29, 1999, http://www.economist.com/node/321433/.

3. The last mile is not the only segment of the network that requires attention, however, since a viable "backbone" is also crucial. *See* Benoît Felten, Diffraction Analysis, Connectivity Models for Developing Economies 2 (Oct. 22, 2013) (unpublished manuscript, *available at* http://ssrn.com/abstract=2343233 ("Without a backbone, little or nothing can happen in the last mile to consumers. If this is identified as the main hurdle for access investment, then this is where public intervention should be primarily focused."). However, regulators increasingly recognize that the last-mile issues are some of the thorniest. *See e.g.*, Speta, *supra* note 2, at 41, 45, 65 (discussing the last mile in the policy context of the United States); *see also* REP. OF KENYA, THE NATIONAL BROADBAND STRATEGY 16 (2013), *available*

solve the deployment problems faced when building out this part of the network in emerging countries, we recognize that other technical solutions or policy variations may fit one region better than another depending on specific local circumstances. It is not possible to create a "one-size-fits-all" solution, but we believe the framework we describe in this Article can engender the necessary focus and debate on key Internet deployment issues.[4]

To understand the motivations for this Article, it is critical to understand the current state of Internet connectivity on a global scale. Many sources provide tracking data regarding who is online and who is not, along with the current status of deployments and measurements of progress. One commonly used source is the International Telecommunication Union ("ITU"). According to the ITU, 2.7 billion people, or 39% of the global population of 7 billion, use the Internet today.[5] The question of how to connect the remaining 4.3 billion people in the world to the Internet is thus receiving an increasing amount of attention from international organizations like the United Nations ("UN"), as they study the implementation of the Millennium Development Goals.[6] The goal of connecting the "next five

at http://www.cck.go.ke/resc/publications/Broadband/National-Broadband-Strategy.pdf ("Last mile access continues to pose the greatest challenge to connectivity and operators are promoting multiple solutions to address unique challenges."); MANDLA MSIMANG, INFODEV, BROADBAND IN KENYA: BUILD IT AND THEY WILL COME 23 (2011), *available at* http://www.infodev.org/infodev-files/resource/InfodevDocuments_1108.pdf ("Last mile access remains a challenge, however it is surmountable using a combination of private and public funding, and regulatory and policy clarity.").

4. While beyond the scope of this article, other barriers such as regional instability, currency risk, or corruption may be much more important than last-mile access. This is because the deterrents for investors are so unbelievably high in places like Somalia, Iran, and China, and risk assessment in emerging markets is a complicated field. In addition, certain factors influencing last-mile access, such as decentralization, have political importance. Decentralization makes it more difficult for a particular actor to exert control over others. For example, Russia uses its control over centralized gas lines to control other Eastern European countries. *See* Suzanne Lynch, *Russia Still Wielding Its Power over Eastern Europe*, IRISH TIMES (Nov. 29, 2013), http://www.irishtimes.com/news/world/europe/russia-still-wielding-its-power-over-eastern-europe-1.1610785/.

5. *See* ICT DATA & STATISTICS DIV., INT'L TELECOMM. UNION, THE WORLD IN 2013: ICT FACTS AND FIGURES (2013), *available at* http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2013-e.pdf [hereinafter ICT FACTS AND FIGURES].

6. The UN Millennium Goal that pertains to Internet adoption and Internet access is "Target 18," calling for "cooperation with the private sector [to] make available the benefits of new technologies, especially information and communication technologie." *Goals, Targets and Indicators*, UN MILLENNIUM PROJECT, http://www.unmillenniumproject.org/goals/gti.htm (last visited Feb. 7, 2014); *see also* UNITED NATIONS, THE MILLENNIUM DEVELOPMENT GOALS REPORT 56–57 (2013), *available at* http://www.un.org/millenniumgoals/pdf/report-2013/mdg-report-2013-english.pdf [hereinafter: MDG REPORT

billion" people corresponds to the time when the world population reaches 7.7 billion. The UN projects that the population will reach 7.7 billion in 2020 and 8.4 billion in 2030.[7] If this projected growth rate is correct, what does it mean for the next five billion? Given that the annual growth in global Internet users is a relatively robust 8%, compounded annual growth under this rate means that the number of Internet users would double in nine years and reach 7.3 billion in thirteen years (roughly in the year 2025).[8] Thus, on some level, even if nothing is done, if the same growth rates continue, then theoretically, 4.6 billion of the next five billion will be covered in the next eleven years.

However, full adoption by the global population will never be achieved because a persistently high volume of the population will never use the Internet (at least not directly). Significantly, about 26% of the world's population is less than 14 years old.[9] A study from the Sesame Workshop[10] shows that a significant portion of this 26% would theoretically be able to use the Internet (25% of children under the age of three go online).[11] The reality of the Internet's actual use by children clashes with the many child-protection statutes that are drafted in a way that purports to complicate, deter, or restrict youth from using the Internet at all until a certain age.[12]

2013] ("More efforts must be made to make broadband available, affordable and truly high-speed for all.").

7. *See World Population Prospects: The 2012 Revision—Population*, UN DEP'T OF ECON. & SOC. AFF., http://esa.un.org/unpd/wpp/unpp/panel_population.htm (last visited Feb. 7, 2014) [hereinafter *World Population Prospects*] (select "Population" from list of variables and "World" from list of regions; then click "Display" button).

8. *See* Mary Meeker & Liang Wu, Kleiner Perkins Caufield & Byers, Presentation at 2013 D11 Conference: Internet Trends, slide 4 (May 29, 2013), http://www.slideshare.net/kleinerperkins/kpcb-internet-trends-2013/.

9. *World Population Prospects*: *The 2012 Revision—Detailed Indicators*, DEP'T OF ECON. & SOC. AFF., http://esa.un.org/unpd/wpp/unpp/panel_indicators.htm (last visited Feb. 7, 2014) (select "Population aged 0–14" from list of variables and "World" from list of regions; then click "Display" button).

10. SESAME WORKSHOP, http://www.sesameworkshop.org/ (last visited Apr. 19, 2014).

11. AVIVA LUCAS GUTNICK ET AL., SESAME WORKSHOP, ALWAYS CONNECTED: THE NEW DIGITAL MEDIA HABITS OF YOUNG CHILDREN 16 (Apr. 2011), *available at* http://www.joanganzcooneycenter.org/wp-content/uploads/2011/03/jgcc_alwaysconnected.pdf ("At age 3, about one-quarter of children go online . . . [a]nd by age 8, more than two-thirds use the Internet in any given weekday.").

12. *See, e.g.*, Children's Online Privacy Protection Act of 1998, Pub. L. No. 105-277, § 1303, 112 Stat. 2681, 2681–728, 730 (codified at 15 U.S.C. § 6502 (2012)) (mandating that website operators obtain "verifiable parental consent" before collecting most kinds of personal information of children under the age of thirteen).

Many studies only start analysis of children's use of the Internet at age nine.[13] The data is not yet available to make an accurate prediction for what proportion of the projected population of 7.7 billion who are children will be online.

In addition to babies and youth, there are nearly one billion global citizens that are illiterate.[14] Although not all uses of the Internet require the ability to read or write (particularly applications that involve sound or video), it seems evident that those citizens who have not learned to read or write are unlikely to have the skills required to contract for many Internet services, to digitally sign the plethora of click-wrap agreements that most Internet services require, or to have the economic ability to purchase many services. There are many definitions of illiteracy, and the World Literacy Foundation has included in their definition of "functional illiteracy" the inability to use the computer or smartphone for news, email, social networking, banking, and interactive Internet functionality.[15]

On some level, the previous analysis may mean that it is folly to speak of connecting the next five billion. After all, we do not yet know how many children or youth actually use the Internet globally, nor is it clear how many of the one billion illiterate (or possibly more "functionally illiterate") people will use the Internet. In spite of this, we believe that speaking of the next five billion is a useful conceptual framework: Youths are likely to live with adults capable of connecting to the Internet. It is likely that technology will grow to accommodate more and more users with disadvantages of all kinds, including illiteracy.[16] And citizens that live in countries that block websites or restrict Internet usage will have limited access, but access nonetheless. For these reasons, we believe that tracking overall population numbers is a useful, if technically inaccurate, proxy for global connectivity.

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13. *See, e.g.*, SONIA LIVINGSTONE ET AL., EU KIDS ONLINE, SOCIAL NETWORKING, AGE AND PRIVACY (2011), *available at* http://www.lse.ac.uk/media@lse/research/EUKidsOnline/EU%20Kids%20II%20(2009-11)/EUKidsOnlineIIReports/ShortSNS.pdf (surveying Internet use in Europe by children of nine to sixteen years old).

14. *See* ANTHONY CREE, ANDREW KAY & JUNE STEWARD, WORLD LITERACY FOUND., THE ECONOMIC & SOCIAL COST OF ILLITERACY: A SNAPSHOT OF ILLITERACY IN A GLOBAL CONTEXT 2 (2012), *available at* http://www.worldliteracyfoundation.org/The_Economic_&_Social_Cost_of_Illiteracy.pdf ("[M]ore than 769 million people in the world cannot read and write.").

15. *Id.* at 3.

16. *See generally* Donald J. Leu, Jr., *Literacy and Technology: Deictic Consequences for Literacy Education in an Information Age*, *in* 3 HANDBOOK OF READING RESEARCH 743 (Michael L. Kamil et al. eds., 2010), *available at* http://www.sp.uconn.edu/~djleu/Handbook.html (discussing information technologies' ability to reduce illiteracy).

Finally, lessons learned from telephone networks also indicate that full penetration may never be possible. Although the fixed phone system has been in place for more than a century, in some countries, like India, the penetration rate of fixed lines has never exceeded twenty percent.[17] There, landline usage was quickly eclipsed by mobile phone usage, which reached more than fifty percent within a decade of its launch in the late 1980s.[18] Despite some inherent ceilings on market penetration, Internet deployment should be able to capitalize on the same infrastructure investments of fixed wireline and mobile: they can share utility poles, trenches, conduits, access to power, and similar resources. Moreover, Internet deployment could also encourage development of new technologies such as satellite and even wireless-enabled balloons,[19] even though the market and industry players have often underestimated demand for[20] or actively resisted[21] new technologies.

It is unlikely that the infrastructure required for the next five billion is going to be built without significant buy-in and collective effort from the private sector, individual governments, and other stakeholders. With this in mind, we must determine where the focus of broadband deployment should occur in the world in order to achieve the five-billion goal by a certain date—and for our purposes, even with the caveats noted above, we will assume that the target date is 2030. Table 1 shows a breakdown of regional sources of global population growth from the UN population estimates.[22]

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17. *Mobile Phones: A Global Revolution*, ASPEN INST., http://www.aspeninstitute.org/policy-work/communications-society-21 (last visited Feb. 7, 2014).

18. *Id.*

19. *See Project Loon*, GOOGLE, http://www.google.com/loon/ (last visited Feb. 7, 2014) ("Project Loon is a network of balloons traveling on the edge of space, designed to connect people in rural and remote areas, help fill coverage gaps, and bring people back online after disasters.").

20. For example, AT&T developed the technology for cellular communications, then famously sold its technology to Craig McCaw because the company believed cell phones would be a niche product affordable only to extremely wealthy individuals like investment bankers, doctors, and lawyers. *See* Jeffrey S. Young, *Craig McCaw—The Wireless Wizard of Oz*, FORBES (June 22, 1998), http://www.forbes.com/1998/06/22/feat.html (describing Craig McCaw's vision about how cellular phones would change the world, something that telecom giant AT&T completely missed at the time).

21. *See generally* TIM WU, THE MASTER SWITCH (2010) (giving numerous examples throughout the twentieth century of entrenched information-technology empires resisting innovation that would challenge their dominant position).

22. Data is gathered from *World Population Prospects*, *supra* note 7. Though close, these four regions do not fully represent the entire population of individuals throughout the world, as there are some smaller countries not included in these categories. The forecasted population of these regions in 2030, for example, accounts for 98.9% of the forecasted total

Table 1. Population Growth by Region Through 2030

	Population in 2010	Population in 2030	Population Growth	% of Total World Population Growth
Asia	4.2B	4.9B	0.7B	47%
Africa	1B	1.6B	0.6B	40%
Americas	0.9B	1.1B	0.2B	13%
Europe	0.7B	0.7B	0	0

Using ITU data estimating the number of Internet users per one hundred inhabitants,[23] Table 2 shows a rough estimate of the breakdown of new Internet users by region. As shown, it is expected that Asia will account for 62% of new Internet users through 2030, and Africa will account for just over one quarter of the new users at 26%. Clearly, efforts to connect new Internet users will have to focus directly on Asia and Africa in order to succeed. Indeed, the UN Millennium Development Goals also place a particular emphasis on certain regions.[24]

As we noted above,[25] a straightforward projection of the current 8% annual adoption rate for the Internet would appear to support a proposition that the next five billion users could come online between 2025 to 2030. The breakdown of new Internet users by region in Table 2 indicates that achievement of this goal is within reach (at least defined by the current 8% growth rate) throughout most of the world except for Africa, which requires a much higher annual adoption rate of 13.9% to hit the target by 2030.[26] The

world population using these figures. Nevertheless, we assume that these four regions essentially represent the total world population throughout this discussion.

23. The regional breakdown of the ITU statistics differs slightly from the regional breakdown we have reported here. Most notably, the ITU statistics include the Arab States and Commonwealth of Independent States. We have not made any adjustments in our calculations to incorporate the penetration rates of Internet users within these regions into the corresponding regions in our analysis. *See* ICT FACTS AND FIGURES, *supra* note 5.

24. *See* MDG REPORT 2013, *supra* note 6, at 56–57 ("In the developing world, 31 per cent of the population are online, compared to 77 per cent in the developed world. Sub-Saharan Africa, where less than 20 per cent of the population are using the Internet, remains the region with the lowest penetration rate.").

25. *See supra* note 5 and accompanying text.

26. One could argue that the early stage of Internet adoption in Africa may be able to support above-average adoption rates for the region, though it would be an unmistakably

reality, therefore, is that significant challenges exist in connecting most of these next five billion users, particularly in terms of deploying the last mile of infrastructure needed to extend the Internet into regions where these users reside. Until these deployment barriers are resolved, the growth rate of Internet users is likely to remain fairly static.[27]

Table 2. Breakdown of New Internet Users by Region (Regional breakdown from the ICT Report)

	Internet Penetration Today	Target Penetration for 5B	New Internet Users to Hit Target by 2030	% of Total World User Growth	Needed Annual Growth
Asia	32%	90%	3.1B	62%	7.3%
Africa	16%	90%	1.3B	26%	13.9%
Americas	61%	95%	0.5B	10%	3.9%
Europe	75%	95%	0.1B	2%	1%

Part II identifies significant barriers to the deployment of last-mile broadband networks in emerging countries. Part III describes last-mile network options, and Part IV presents broadband roadmaps for developing countries given these options. Part V identifies the government policies we suggest are best suited to significantly increase Internet penetration in emerging countries.

Information for this study was gathered from a review of published, publically available sources and interviews with subject matter experts internal to Google.[28]

optimistic position to take. Assuming an 8% compounded growth rate in Internet adoption, it would take Africa 29 years, or until 2042, to realize 1.3 billion new Internet users.

27. Thus, if the average growth rate were to fall to 4% this year and remain constant thereafter, it would take eighteen years to double the number of Internet users that exists today and twenty-six years to reach 7.3 billion global users.

28. The authors are grateful to the following people who provided thoughts and ideas included in this section (while not speaking for them nor representing a consensus view): Nnamdi Abraham-Igwe, Larry Alder, Eric Brewer, Alan Norman, Arun Majumdar, Milo Medin, Aparna Sridhar, Austin Schlick, and Kai Wulff.

II. BARRIERS TO BROADBAND DEPLOYMENT

Our study uncovered numerous barriers to broadband deployment in emerging countries or countries with economies that are in the early-adoption stage of the Internet. These include the significant need for low-cost broadband equipment that will work on easy-to-install solar energy units and a public-policy framework that encourages a shared infrastructure development strategy among infrastructure players. We also found important business concerns, though consideration of these issues is beyond the scope of this Article.[29] Instead, we will focus only on what we believe to be key technical and policy barriers for broadband deployment. This focus is justified to the extent that solutions to the major technical and policy barriers should lay the foundation for addressing the business problems in due course.

A. TECHNOLOGY BARRIERS

The lack of electricity and a dearth of low-cost network solutions in the last mile of unserved or underserved areas are significant technical barriers to broadband deployment.

1. *The Problem of Electrical Power*

For many developing regions, the absence of electricity to power network equipment operating the last-mile network infrastructure is a significant issue, particularly in Sub-Saharan Africa.[30] A 2010 report by the World Bank offered the following sober statistics:[31]

- Installed generation capacity of forty-eight Sub-Saharan African countries is only sixty-eight gigawatts—no more than that of Spain—with up to 25% of capacity unavailable due to aging plants and poor maintenance.[32]
- Only approximately 20% of the Sub-Saharan African population has access to electricity (compared to about 50% in South Asia

29. For example, key business concerns could include the lack of disposable income available to pay for infrastructure, little consensus on the appropriate pricing structure for Internet service, or a lack of demand for the Internet due to limited Internet content in the language of the region.

30. *See* Morgan Bazilian et al., *Energy Access Scenarios to 2030 for the Power Sector in Sub-Saharan Africa*, 20 UTIL. POL'Y 1, 1 (2012) ("Current actions to eliminate energy poverty are falling short both in terms of scale and pace. In fact, if current trends continue, more people in Africa will be without access to modern energy services in 2030 than today.").

31. *See* AFRICA'S INFRASTRUCTURE: A TIME FOR TRANSFORMATION 181–202 (Vivien Foster & Cecilia Briceño-Garmendia eds., 2010).

32. *Id.* at 182.

and more than 80% in Latin America). Of these, 71% of homes in urban areas, and only 12% of homes in rural areas, have access to electricity. Notably, two-thirds of the total population live in rural areas, further complicating and raising the expense of extending the electrical grid to more homes.[33]

- The average cost of power in Sub-Saharan Africa is high at $0.18 per kilowatt-hour (compared to $0.04–$0.07 per kilowatt-hour in Asia). Due in part to this high cost, Sub-Saharan Africa is the only region in the world where per-capita power consumption declined compared to levels measured in 2005 by a similar World Bank study.[34]
- Per-capita electricity consumption in Sub-Saharan Africa (excluding South Africa) averages 124 kilowatt-hours per year. This amount is barely 1% of the consumption typical in developed countries, hardly enough power to light "one light bulb per person for six hours a day."[35]

These statistics indicate that the availability of electrical power from a centralized grid represents a major barrier to deployment of last-mile networks in Sub-Saharan Africa. Although we do not have comparable statistics available, colleagues we interviewed indicated that similar limitations exist within emerging countries in Asia.[36]

Our interviews with network and power experts in emerging countries uncovered two key anticipated technology advances that will serve to scale this barrier.[37] First, because of the high cost and difficulty of extending the existing, centralized grid, decentralized grid solutions such as solar power could be developed and implemented for last-mile networks. The advantage of a centralized grid approach is the ability to capture economies of scale through the use of large, shared power plants or hydroelectric dams.[38] Economies of scale will likewise be essential in any decentralized powering solution—the key difference being that scale in the decentralized approach will be derived from volume production of power system components (e.g., solar energy panels) versus a high degree of shared infrastructure in a

33. *Id.*
34. *Id.*
35. *Id.*
36. *See supra* note 28.
37. *Id.*
38. *See* JEREMI MARTIN, HEC PARIS, DISTRIBUTED VS. CENTRALIZED ELECTRICITY GENERATION: ARE WE WITNESSING A CHANGE OF PARADIGM? 8 (2009), *available at* http://www.vernimmen.com/ftp/An_introduction_to_distributed_generation.pdf.

centralized grid. Borrowing from the experience of telecommunication systems, the future decentralized solution may thus require a simplified "plug-and-play" implementation between power generation and storage units in order to succeed.[39]

There is reason to be optimistic regarding the development of such a system, though a review of the near-term technologies driving this optimism is beyond the scope of this Article. The cost of solar panels is forecast to significantly decline through 2020.[40] In the United States, the Department of Energy has set a goal for solar cost below $1 per watt, which would make the direct cost of solar power fall below $0.06 per kilowatt-hour (less than the current cost of power generation using new natural-gas plants).[41] Energy storage to smooth out power availability from renewable power sources on micro-grids is also benefitting from economies of scale, though at a slower pace.[42]

Second, the rollout of last-mile telecommunications systems will drive the development and deployment of the electrical grid in unserved or underserved areas, not vice-versa. The statistics indicate that geographic coverage for cellular networks in emerging countries is likely to reach well above the majority of the population even though the same population does not have access to electricity.[43] Thus, supporting the power requirements of cellular infrastructure is the reason for introducing electricity into these unserved areas, leaving open the opportunity to provide power for other

39. "Plug and play" in this context means that a micro-grid could be created simply and inexpensively through standardized interconnection of system components. For examples of research in this area, see *Plug and Play Distributed Power Systems for Smart-Grid Connected Building*, DEP'T OF ENERGY, http://energy.gov/eere/buildings/plug-and-play-distributed-power-systems-smart-grid-connected-building/ (last visited March 21, 2014).

40. McKinsey & Company forecasts costs for the solar-photovoltaic section to drop as much as 10% annually through 2020. *See* KRISTER AANESEN, STEFAN HECK & DICKON PINNER, MCKINSEY & CO., SOLAR POWER: DARKEST BEFORE DAWN 1 (2012).

41. *See* Kevin Bullis, *What Tech Is Next for the Solar Industry?*, MIT TECH. REV. (June 21, 2013), http://www.technologyreview.com/news/516306/what-tech-is-next-for-the-solar-industry/.

42. *See* Peter Kelly-Detwiler, *Energy Storage: Continuing to Evolve*, FORBES (May 15, 2013), http://www.forbes.com/sites/peterdetwiler/2013/05/15/energy-storage-continuing-to-evolve (discussing developments in energy storage technology, while noting that it "still [has] a way to go to reach the mainstream").

43. For example, in the East African countries of Kenya, Tanzania, and Uganda, mobile networks covered 80% of the population and about 50% of the land area in 2011; mobile coverage is close to 100% for the urban population and 73% for the rural population. *See* GSM ASS'N, INT'L FINANCE CORP., POWERING TELECOMS: EAST AFRICA MARKET ANALYSIS 8 (2012), *available at* http://www.gsma.com/mobilefordevelopment/wp-content/uploads/2012/10/GPM-Market-Analysis-East-Africa-v3.pdf.

applications in the process. One company in India—OMC[44]—does just this, working with mobile operators as anchor tenants, demonstrating that mobile telephony and cellular-tower infrastructure can in fact drive the power grid's growth.[45] Modifications to standard cellular equipment are possible to further reduce powering costs for rural cellular environments.[46]

The discussion above focuses on the problem of powering the network equipment of last-mile networks but applies as well to providing power to the consumer devices that will connect to the Internet. Consumer devices need electricity to operate, though they require lower amounts of power and need not be as reliable compared with network equipment. Powering of consumer devices can take advantage of micro-grid technology that integrates one or more power sources into low-voltage electricity systems. This technology can distribute excess power generated at one or more network nodes housing network equipment to nearby household or community locations, or it can distribute power generated in a single location to other households in the community. The best approach for micro-grid systems will vary with the type of broadband network employed. As a general rule, a wireless network for broadband would favor smaller, more distributed micro-grids, while a wireline network could have more shared infrastructure through the joint placement of a larger grid of power and networking cables.

The implications of these new technical developments are important. The problem of obtaining low-cost power for last-mile networks is significant, particularly in Sub-Saharan Africa, which could account for over a quarter of future Internet users.[47] The cost and effort to build a traditional, centralized grid solution represent substantial barriers to the rapid deployment of last-mile broadband networks. Emerging countries, such as those in Sub-Saharan Africa, need a low-cost distributed power generation solution that complements the topology of the last-mile broadband network. To be cost effective, this new solution needs to be simple to install, capable of capitalizing on anticipated advances in solar and energy storage

44. OMC POWER, http://www.omcpower.com/ (last visited Apr. 19, 2014).

45. *See* Tina Rosenberg, *The Next Wireless Revolution, in Electricity*, N.Y. TIMES: OPINIONATOR (Sept. 11, 2013), http://opinionator.blogs.nytimes.com/2013/09/11/the-next-wireless-revolution-in-light/ (describing various innovations in power with a focus on the work of OMC).

46. *See* Kurtis Heimer et al., *Expanding Rural Cellular Networks with Virtual Coverage*, *in* NSDI '13: 10TH USENIX SYMPOSIUM ON NETWORKED SYSTEMS DESIGN AND IMPLEMENTATION 283, 283 (2013) (describing a "prototype cellular system utilizing virtual coverage by modifying a GSM [Global System for Mobile Communications] base station and a set of Motorola phones to support making and receiving calls").

47. *See supra* Table 2.

technologies, and complementary to broadband technology (e.g., it will need to be co-located with wireless tower deployments).[48]

As we will discuss further in Part III, these requirements establish the need for the development and manufacture of low-cost broadband equipment that will operate on easy-to-install solar energy units, both in the network infrastructure and for consumer devices. It is unlikely that an incremental approach to the current power distribution model can achieve this goal; instead, a more radical or disruptive approach to the centralized grid based on solar-photovoltaic technology will be needed to meet the substantial cost and ease-of-use requirements.[49] This is consistent with data indicating that rural electrification projects funded by the World Bank, for example, increasingly have an "off-grid" component.[50]

2. Lack of Low-Cost Network Solutions

Figure 1 shows the basic segments of a broadband network typically found in emerging countries. As a general rule, the cost of deployment of each network segment increases on a cost-per-user metric, starting with the investment and maintenance costs of the international landing point and progressing through the network toward the last-mile segment. Therefore, the lack of low-cost network solutions for the last-mile infrastructure represents another significant technology barrier to implementing broadband in developing regions. Within Africa, for example, the cost of the last mile

48. Beyond cost, another barrier to deployment of solar technology is the high cost of vandalism and lack of security in some areas. *See* Kokumo Goodie, *Why Solar-Powered BTS Is Unpopular*, BIZTECH AFR. (Jan. 20, 2014, 8:27 AM), http://www.biztechafrica.com/article/why-solar-powered-bts-unpopular/7561/#.U1GC5OZdWd8 ("The cost of acquiring land, solar panels and vandalism are some of the reasons why telecom operators are not embracing renewable energy . . . .").

49. Analysts from McKinsey write:

> Rapid growth of distributed generation could disrupt the regulated utility industry in countries that belong to the Organisation for Economic Co-operation and Development (OECD). In non-OECD countries, distributed generation (in combination with inexpensive storage solutions) could bring electricity to millions of poor people living in rural areas, greatly improving their standard of living.

AANESEN, HECK & PINNER, *supra* note 40, at 2–3.

50. INDEP. EVALUATION GRP., WORLD BANK, THE WELFARE IMPACT OF RURAL ELECTRIFICATION: A REASSESSMENT OF THE COSTS AND BENEFITS 76, tbl.B.11 (2008) (showing the percentage of projects with an off-grid component increasing to 59.6% during the period 1996–2006, compared to 4.3% between 1980–1995).

accounts for roughly 45–60% of the total costs of the network segments (excluding customer premises equipment costs).[51]

Figure 1. Broadband Network Segments in Emerging Countries

Robert Schumann and Michael Kende have developed one of the most comprehensive reports (together with the Internet Society) examining the barriers to Internet deployment in Africa, with a primary focus on international connectivity, the national backbone, and metropolitan-area network components.[52] The report concludes that Internet development is still restricted by constraints in connectivity among submarine cables, the Internet Exchange Points ("IXPs"), and last-mile access infrastructure.[53] We note that the role of IXPs in this space is relatively new in academic literature,[54] and we address the topic further in Part V.

B. POLICY BARRIERS IN THE LAST MILE

The key policy barriers to broadband deployment in unserved areas are (1) the lack of public-policy framework for interconnection and infrastructure and (2) an overall lack of government leadership.

Bringing the Internet to unserved areas requires a lower-cost last-mile network.[55] The idea of "infrastructure sharing" is consistently offered as an expedient way to reduce network costs. Under typical sharing models, utility-based infrastructure companies delivering power, water and sewage, or transportation (e.g., highway and railway) share the cost of installing and maintaining facilities that traverse rights-of-way or remote office locations. For example, shared infrastructure coordination can mean that more than

51. *See* ROBERT SCHUMANN & MICHAEL KENDE, LIFTING BARRIERS TO INTERNET DEVELOPMENT IN AFRICA: SUGGESTIONS FOR IMPROVING CONNECTIVITY 13 (2013), *available at* http://www.internetsociety.org/doc/lifting-barriers-internet-development-africa-suggestions-improving-connectivity/.

52. *Id.* at 8–9.

53. *Id.* at 5. The existence of comprehensive overviews of the current state of development of international connectivity, the national backbone, and metropolitan area network components in Africa is one reason that we chose to focus on a different and equally important segment of the network: the last mile.

54. *See generally* Jason Gerson & Patrick Ryan, A Primer on Internet Exchange Points for Policymakers and Non-Engineers (Aug. 11, 2012) (unpublished manuscript), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2128103.

55. *See supra* Subection II.A.2.

one company can use space on poles that carry aerial plants or conduit buried underground for cables. Each utility provider need not reinvent the wheel.

As noted above,[56] broadband and electricity are complementary services, pointing to potentially substantial economic savings in the joint provision of the two services. Thus, a public policy framework that encourages or even rewards a shared infrastructure development strategy among infrastructure players is desirable. As we emphasized earlier, this framework needs to nurture and encourage the development of disruptive, innovative powering solutions as well.[57] Part V describes some of the policy principles that could serve as a catalyst for the efficient and timely deployment of shared infrastructure.

As a corollary, such policy frameworks necessarily require the backing of the governments in the region. A more proactive government approach could help many emerging countries extend the Internet to unserved areas. Government leadership in this realm does not necessarily entail passing new laws, but instead providing a vision—including the goals and incentives—for deploying broadband. This point is supported by a joint study carried out by the ITU and Cisco Systems demonstrating that countries with a clearly defined national vision for broadband outperform those without one.[58] Beyond the technical difficulties inherent in expanding broadband coverage,[59] additional hurdles—such as government red tape or incumbent providers dragging their feet in the interconnection process—pose substantial barriers to network deployment.[60] Governments can pursue these and other actions at various degrees of engagement, ranging from an aggressive leadership strategy with industry and civil society to eliminate broadband deployment barriers, to a more hands-off model, so long as the regulatory structure enables such an approach. Before reaching these proposed plans, we outline the available last-mile network options.

56. *See supra* Subection II.A.1.

57. *See supra* note 49 and accompanying text.

58. CISCO SYS. & INT'L TELECOMM. UNION, PLANNING FOR PROGRESS: WHY NATIONAL BROADBAND PLANS MATTER 7 (2013), *available at* http://www.broadbandcommission.org/documents/reportNBP2013.pdf [hereinafter PLANNING FOR PROGRESS] (describing the rollout of broadband in different economies and concluding that countries that have a broadband plan outperform those that do not by a factor of as much as 7.4%).

59. *See supra* Section II.A.

60. In Part V, we outline further details of what policy elements could be included for this and other matters addressed in this study.

III. LAST-MILE NETWORK OPTIONS

Despite the technical and policy barriers to last-mile network deployment, a number of last-mile technologies are currently under consideration or development for use in unserved regions of emerging countries. This Part describes these last-mile network options and some of the recent trends impacting the cost or capabilities of last-mile platforms.

A. CATEGORIZING LAST-MILE OPTIONS

We choose to categorize the last-mile network options to support broadband Internet services in emerging countries into four groups depending on whether or not they are predominantly wireless, the level of mobility supported by the wireless or wireline network, and the amount of optical fiber found in the wireline network. The four categories are as follows:

1. Mobile Wireless

Mobile wireless network platforms support broadband access using radio connections to end-user devices in conjunction with mobile telephone or cellular services. Mobile functionality permits users to maintain seamless network sessions and connections while in motion through the entire area of network coverage.

2. Portable Wireless

Portable wireless network platforms, such as Wi-Fi, support broadband access using radio connections to end-user devices. The wireless connection gives end users the flexibility to move within the coverage area of a specific radio transmitter in the network. However, the platform does not support long-range mobility—the network session or connection must be broken and then reestablished if end users move between the coverage areas of two different network transmitters. Similar portable wireless platforms that we do not include as viable options in emerging countries are wireless local loop and satellite direct-to-home options, since both platforms have not enjoyed substantial adoption anywhere in the world for broadband services at this time.[61]

61. This is not to suggest that wireless transport links (e.g., microwave) and satellite links in the national backbone and metropolitan area network are not an option. As discussed in Part IV, *infra*, microwave and satellite links may become important technologies to consider in the broadband roadmaps for emerging countries.

3. *Legacy Wireline*

Legacy wireline network platforms are based on the existing telephone or telecommunications service provider in the region. This network consists of fiber-optic cables in the metropolitan area network and twisted, copper-wire pairs in the last-mile portion of the network that stretches to the end user.[62] Legacy cable networks based on fiber-optic and coaxial cable are notably absent in most emerging countries.

4. *Fiber Network*

Fiber-network platforms consist solely of fiber-optic cable from the core network all the way to the premises of the end users. While the fiber-optic cable itself does not require network equipment that needs electrical power, the optical-line termination unit at the location of the end user does require electrical power.

* * *

More than one transport technology can be used within each of these categories. The transport alternatives vary by the network architecture, cost, and speed of broadband access they provide. Tables 3 through 6 provide a breakdown of the major transport alternatives for deployment in emerging countries for the four categories listed above. The tables sort the alternatives into three broadband speeds that the deployed technologies would likely provide: less than 10 Mbps, between 10–100 Mbps, and more than 100 Mbps. For each of the alternatives, Tables 3 through 6 also include a brief description of each technology's key strengths and limitations.

62. *See supra* Figure 1.

Table 3. Mobile Wireless Options

Below 10 Mbps Broadband Solutions
3G Mobile **(Technical standard:** 3G Cellular (ITU IMT-2000))[63] *Strengths* o Relative low cost to deploy and availability of used equipment o Use for fixed wireless access (minimum data rate of 2 Mbps) *Limitations* o Lack of standard frequency bands could impact device interoperability o Minimum mobile data rates of 384 Kbps downstream, 300 Kbps upstream
10–100 Mbps Broadband Solutions (100+ Mbps not applicable due to cost)
4G or Long-Term Evolution ("LTE") (**Technical standard:** ITU IMT-Advanced)[64] *Strengths* o Broadband platform design with an emerging ecosystem to support it o Ability to target high-density areas using licensed spectrum below 1 GHz o Peak downstream rates of 100 Mbps for mobile and 1 Gbps for fixed/<100 Mbps in the upstream *Limitations* o Higher cost to support higher bandwidths o Sufficient spectrum allocations required to support higher data rates o Lack of standard frequency bands could impact device interoperability

63. *See generally About Mobile Technology and IMT*-2000, INT'L TELECOMM. UNION, http://www.itu.int/osg/spu/imt-2000/technology.html (last visited Apr. 1, 2014) (describing ITU 3G technology standards).

64. *See generally* INT'L TELECOMM. UNION, REQUIREMENTS RELATED TO TECHNICAL PERFORMANCE OF IMT-ADVANCED RADIO INTERFACE(S) (2008), *available at* http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2134-2008-PDF-E.pdf (describing the technical requirements built into 4G or IMT-Advanced standards).

Table 4. Portable Wireless Options

Below 10 Mbps Broadband Solutions	
Satellite (Implementation examples: *O3b Networks, YahClick*)[65] *Strengths* ○ O3b: Transition to low/medium earth orbit deployments with lower latency supports voice and increases speed from ~100 Kbps to 10 Mbps; Yahclick: Ka band satellites ○ O3b: Ability to target rural settings connecting to shared customer segment sites that fan out with shared Wi-Fi or mobile; Yahclick: direct to the consumer data service from ~100 Kbps to 10 Mbps ○ Good IP video broadcast platform ○ Satellites support 1 Gbps spot beams *Limitations* ○ Line-of-sight effectively required ○ Costly launch of satellites ○ O3b: costly ground equipment is unavailable for consumers (only ISPs and resellers); Yahclick: costly ground equipment for each user ○ Lack of capacity for high-bandwidth services such as HD	**Balloon** (Implementation example: *Project Loon*)[66] *Strengths* ○ More dynamic platform than satellite (more rapidly deployed and at a lower cost) ○ Radio coverage of 20–50 km fits between satellite spot-beam and macrocell mobile platforms ○ Ability to target rural, peri-urban settings using direct-to-consumer model (as either a niche or general solution) ○ Regulatory framework less constraining than satellites *Limitations* ○ Line-of-sight effectively required ○ Regulatory framework likely to mirror that of satellites ○ Experimental technology ○ Access speed dependent upon spectrum allocation

65. O3B NETWORKS, http://www.o3bnetworks.com/ (last visited Feb. 7, 2014); YAHCLICK, http://www.yahclick.co.za/homepage/ (last visited Apr. 19, 2014).
66. *Project Loon*, GOOGLE, http://www.google.com/loon/ (last visited Feb. 7, 2014).

10-100 Mbps Broadband Solutions (100+ Mbps not applicable due to cost)	
Unlicensed Wi-Fi (Technical standard: *IEEE 802.11*)[67] *Strengths* o Well-established platform drives down costs o Access speed can exceed 100 Mbps o Attractive "Fiber-to-Wi-Fi" solution due to low cost and high radio capacity *Limitations* o Small cell size o Substantial backhaul network needed o Portability, not mobility	**Unlicensed White Spaces** (Technical standard: *IEEE 802.11af*)[68] *Strengths* o Lower cost than LTE o Increasingly attractive option if LTE is too costly for desirable spectrum *Limitations* o Less capable solution than LTE o Equipment ecosystem is in the early stages of development o Portability, not mobility

Table 5. Legacy Wireline Options

Below 10 Mbps Broadband Solutions
Asymmetrical Digital Subscriber Line (ADSL) (E.g., ITU Recommendation ITU-T G992.1)[69] *Strengths*

67. *See generally* IEEE 802.11 WIRELESS LOCAL AREA NETWORKS, http://grouper.ieee.org/groups/802/11/ (last visited Apr. 11, 2014) (describing the policies and procedures for the IEEE 802.11 working group and how to access the Wi-Fi standards).

68. *Id.* The upcoming IEEE 802.11af standard, also known as Super Wi-Fi, allows Wi-Fi to work in the TV white space spectrum.

69. TELECOMM. STANDARDIZATION SECTOR, INT'L TELECOMM. UNION, ASYMMETRIC DIGITAL SUBSCRIBER LINE (ADSL) TRANSCEIVERS (1999), *available at* http://www.itu.int/rec/T-REC-G.992.1-199907-I/en/. Like solar panels, ADSL deployments also suffer from significant security concerns that can impact the deployment plans of the carriers due to the high risk of copper cable theft. *See Copper Theft Situation Improving*, TECHCENTRAL (Jan. 27, 2014), http://www.techcentral.co.za/copper-theft-situation-improving/46068/; *see also* Goodie, *supra* note 48.

○ Ability to use existing telephone network plant ○ Inexpensive-to-deploy wireline option ○ Downstream speeds up to 8 Mbps and upstream speeds up to 1 Mbps *Limitations* ○ High cost to deploy as compared to wireless ○ Access speed varies with length of copper loop ○ Maximum length of 3 km ○ No support for mobility
10-100 Mbps Broadband Solutions
Very-High-Data-Rate Digital Subscriber Line (VDSL) (E.g., ITU Recommendation ITU-T G993.1)[70] *Strengths* ○ Uses existing telephone network plant ○ Downstream speeds up to 52 Mbps and upstream speeds up to 16 Mbps *Limitations* ○ Expensive to deploy as it requires deep deployment of fiber ○ Access speed varies with length of copper loop ○ Maximum length less than one km ○ No support for mobility
100+ Mbps Broadband Solutions
Currently not applicable or feasible over legacy wireline networks[71]

70. TELECOMM. STANDARDIZATION SECTOR, INT'L TELECOMM. UNION, VERY HIGH SPEED DIGITAL SUBSCRIBER LINE TRANSCEIVERS (2004), *available at* http://www.itu.int/rec/T-REC-G.993.1-200406-I/en/.

71. Even for telephone companies aggressively deploying broadband DSL technology, attaining speeds at or above 100 Mbps is not feasible. *See e.g.*, *AT&T U-Verse High Speed Internet*, AT&T, http://www.att.com/shop/internet/u-verse-internet.html (last visited Apr. 4, 2014) (offering maximum download speeds of 45 Mbps).

Table 6. Fiber Network Option

100+ Mbps Broadband Solutions (<10 Mbps solutions not applicable)
Passive Optic Networks (PONs) (E.g., ITU Recommendation ITU-T G984.1)[72] *Strengths* o Superior option to wireless or legacy network technologies o Up to 2.4 Gbps, symmetric speed (best "future proofing" solution) o Higher capacity per unit area *Limitations* o High cost of deployment o No support for mobility

B. EXAMPLES OF DEPLOYMENTS IN EMERGING MARKETS

A recent study co-developed by Benoît Felten at Diffraction Analysis and Patrick Ryan (one of the authors to this Article) highlights some of the diverse entrepreneurial activities in emerging markets.[73] Excerpts of some of the findings are included below to show how entrepreneurship in both the private and public sectors is alive and well in emerging markets.

1. *Examples of Deployments Wholly Controlled by the Private Sector*

a) Airjaldi in India[74]

One of the most innovative uses of Wi-Fi can be found in Airjaldi, a company based in Northern India. Airjaldi sought to fill a niche by providing broadband solutions that evolved from off-the-shelf Wi-Fi equipment. The business set out to target deep rural markets and geographies that are often very complicated to connect with regular wireline or cellular solutions. In some regions, as in the Himalayas, wireless solutions are the best because of the complications of providing cables for access. Airjaldi is as much of a story of technical innovation as it is of entrepreneurial spirit. The company's operations are extremely lean, and they recruit only among local populations in the areas they cover, training their employees even if they have no

72. TELECOMM. STANDARDIZATION SECTOR, INT'L TELECOMM. UNION, GIGABIT-CAPABLE PASSIVE OPTICAL NETWORKS (GPON): GENERAL CHARACTERISTICS (2008), *available at* http://www.itu.int/rec/T-REC-G.984.1-200803-I/en/.

73. FELTEN, *supra* note 3.

74. *Id.* at 1.

background in IT. Thus, in addition to improving the economy through jobs, Airjaldi is helping to train people in the region who can pass this information along to others in their circles. While Airjaldi's current footprint remains small, the company is expanding fast. The experience thus far shows that rural grassroots initiatives can work with no use of licensed spectrum and limited preexisting IT skills.

b) The Wananchi Group in Kenya[75]

Another example of the creative use of unlicensed spectrum can be found in the case of the Wananchi Group. The Wananchi Group is a large company offering a variety of services to consumers (e.g., satellite TV and broadband services) in Kenya and neighboring countries of East Africa. Under the brand name of Zuku, the Wananchi Group has started to deploy and commercialize a wireline hybrid fiber-copper network to offer triple-play services (i.e., Internet, TV, and telephone) in Nairobi. Although similar hybrid triple-play services are relatively common in the developing world, the Wanachi Group's approach in Kenya is unique because they are looking to share infrastructure assets among players in order to extend Wi-Fi coverage in underserved urban areas. Although the rollout of the services and plans are still in progress, the Wananchi Group's model will help establish that, assuming funding and access to content are in place, there is a business case for wireline triple-play services in urban areas of emerging economies and that wireless can play a role in demand aggregation or coverage extension in parallel to wireline operations.

c) Networx in Bulgaria[76]

In order to understand the kinds of technologies that are successful for emerging markets, it is useful to study the successes of markets that have grown quickly from emerging markets to a mature ones. Bulgaria is a good example because of its roots as a former Soviet country and its passionate embrace of open markets and relentless drive to bring technology to its citizens. In our research, we were impressed with the model of Networx, a Bulgarian Internet Service Provider ("ISP") that started deploying fiber-based broadband services in the early 2000s. Like many technology startups, Networx found its grassroots in a university setting and gradually connected residential buildings with fiber to offer fast broadband when the existing market offered few alternatives. Responding to apparent market demand, Networx expanded from its hometown of Ruse, mostly organically, to

75. *Id.*
76. *Id.* at 1–2.

become one of the largest network operators in Bulgaria. Now that Networx has been around for more than a decade, its model demonstrates that low barriers to entry (notably the absence of barriers of access rights of way) facilitate competition. It also shows that even a wireline network operation can grow and succeed with no initial or external funding if there is limited competition in the market (at least in the early days).

2. Examples of Public-Private Partnerships

The previous examples show that cellular broadband is not the only option for private market participants. However, to assess how public policy and government funding fit in the picture, Felten's report examines three different models of government involvement in Latin America, each affecting different parts of the connectivity ecosystem.

a) Antel in Uruguay[77]

Although the jury is still out on the future of state-owned or state-controlled networks, Antel in Uruguay is a fully state-owned monopoly network operator that is well on its way to providing national fiber-to-the-home coverage (to about ninety-five percent of the population). The model is developing, but Antel does not intend to force migration from copper to fiber (as some other National Broadband Networks ("NBNs") do) but, instead, it generates its fiber offers so that they are competitively priced compared to copper. This model incentivizes natural market behavior and transitions that are driven by user demand rather than by state fiat. And it seems to be working well: the approach has led, thus far, to a take-up rate of over twenty-nine percent in less than two years of operation. Uruguay's example shows the viability of publicly funded access to NBNs for emerging economies. We also observe that Montevideo (and Uruguay as a whole) has more of the characteristics of a city-state than many other regions in Latin America, where rural problems are acute. Still, the success of the model demonstrates that this kind of state-run telecommunication model, if appropriately managed, can bring technology to citizens and drive demand.

b) Backbone Project in Colombia[78]

A public-private partnership in Colombia demonstrates another path towards providing broadband to the country. In Colombia, there are many communities that may never become connected to last-mile services because of the unavailability of a backbone to the Internet. The Colombian Backbone

77. *Id.* at 2.
78. *Id.*

project addresses this problem by financing a national backbone network to connect as many of the 835 (out of 1122) municipalities as possible that did not have any Internet outside of dial-up or satellite as of 2010. In order to accomplish this objective, the Colombian government issued a tender with $200 million of public funding and then awarded to a project connecting 753 of the municipalities. The backbone's deployment will offer both retail and wholesale long-distance services to businesses and operators. The idea is to ensure open-access backbone connectivity. The government makes efficient use of public funding as it unlocks private investment in access. If executed correctly, this can be a particularly effective way to ensure the extension of mobile access coverage. We should note, however, that the rollout of the project is still underway and it is too early to draw any definitive conclusions from the effort.

c) Brazil's Tax Incentives[79]

Brazil is South America's largest economy, and yet it was frustrated with the lack of choices available for Internet Transit and the high costs of obtaining it. In order to address this problem, especially outside of the large population centers, Brazil provided tax incentives as part of a national broadband plan. We should note that it is never easy to use taxes for such incentives because taxation can occur at national, state, and municipal levels, so comprehensive tax programs must be put in place that address all levels. The kinds of tax incentives that Brazil offers are not well defined, and the benefits will need to be clarified to investors in order to incentivize the right kind of financial commitments from the private sector for Internet Exchange Points ("IXPs"), backbones, and other projects that would have the desired effect. If the Brazilian government lays out its case for all investors to understand—and if it negotiates in an equal, non-discriminatory manner with all investors—this model may successfully provide incentives to new entrants in order to provide local infrastructure.

It is too early to tell if Brazil's proposed measures will have a significant impact on transit costs and if that, in turn, will unlock investment in access and boost connectivity, but it is an interesting case study of an attempt to address that particular hurdle, one which is often overlooked. In any event, the use of tax incentives is a much better carrot than the alternative stick that Brazil had previously been promoting, which was to force all multinational providers to localize their data in Brazil.[80]

79. *Id.*

80. *See* Patrick S. Ryan, Sarah Falvey & Ronak Merchant, *When the Cloud Goes Local: The Global Problem with Data Localization*, COMPUTER, Dec. 2013, at 54, 56; *see also* Anupam

IV. BROADBAND ROADMAPS

This Part introduces our view of how broadband networks coverage can expand in emerging countries and how the speed of Internet access service can increase once it is established. We use a broadband roadmap,[81] which describes the evolution of last-mile network deployment and the type of network technology employed to provide increasing levels of access speed to the Internet over time. The cost of network deployment for a particular level of access speed determines the best-fit option among the last-mile network alternatives. A best fit within this context means that a particular general technology from the set of last-mile technology alternatives has the potential to provide the most economical solution.[82] Through the application of this framework, we conclude that wireless technologies are likely to play a prominent role, at least initially, for the last mile of the broadband network in currently unserved, rural areas of emerging countries.

The cost per user of last-mile network deployment varies significantly based on the density of the population in the area where the network is being built. As the distance between households increases in areas with lower population density, the network infrastructure is shared among fewer users, and the amount of network equipment required to serve each user increases due to the longer distances involved in connecting them to the network. The network deployment cost per user in the last mile is therefore inversely

Chander & Uyen P. Le, *Breaking the Web: Data Localization vs. the Global Internet* (Cal. Int'l Law Ctr., Working Paper No. 2014-1, 2014), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2407858 (describing various global initiatives dealing with the data localization and the problems they create by disincentivizing investment and trade).

81. A "broadband roadmap" should not be confused with "national broadband plans." National broadband plans generally do not address specific roadmaps for the deployment of technology and, instead, focus on the following three categories: (1) national broadband coverage (subscriptions and availability), (2) broadband service speeds (primarily download), and (3) economic impact (including employment). *See* Robert Pepper & John Garrity, *Convergent Objectives, Divergent Strategies: A Taxonomy of National Broadband and ICT Plans*, *in* THE GLOBAL INFORMATION TECHNOLOGY REPORT 2013: GROWTH AND JOBS IN A HYPERCONNECTED WORLD 43 (Beñat Bilbao-Osorio, Soumitra Dutta & Bruno Lanvin eds., 2013) [hereinafter GLOBAL INFORMATION TECHNOLOGY REPORT], *available at* http://www3.weforum.org/docs/WEF_GITR_Report_2013.pdf.

82. We should emphasize that this identification is not based on a comparative and detailed engineering cost analysis across the set of alternative last mile technological options. Such an analysis would have to be done on a region-by-region basis in order to develop more refined broadband roadmaps that capture the variations in network deployment costs of last-mile technologies due to specific geographic variations. Instead, we identify the best-fit last-mile categories based on the generally accepted engineering economics of network deployment described below with regard to the costs associated with network speed, population density, wireline versus wireless, and support of mobility.

proportional to population density: as the population density increases, the cost per user decreases. This cost tradeoff intensifies with wireline networks as compared with wireless networks: wireline networks require more infrastructure, and the reduced ability to share its cost in regions of low population density results in sharply increasing network cost per user.

The speed of broadband access also has significant implications for the cost and availability of the last-mile option. The cost per user of last-mile network deployment varies significantly based on the broadband speed delivered to each end user. As the dedicated speed per user increases, the amount of network equipment required to serve each user increases. Hence the cost of the last-mile network is directly proportional to the speed of Internet access service: the faster the broadband, the more expensive the last-mile network solution.

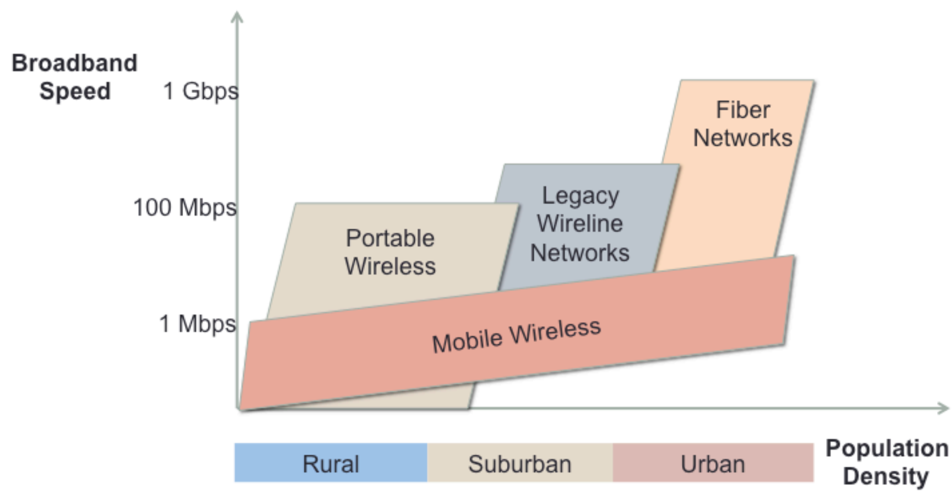
A report by Robert Pepper and John Garrity measures the gap between the coverage and speed of broadband in developed versus emerging countries in 2011.[83] The broadband roadmaps that we describe in this Part can help close these gaps. Unfortunately, the cost to improve both of these factors can be significant. Even so, we believe that once the technological path is understood and policy barriers to its implementation are cleared away, additional investment is likely to emerge organically. While there is no magic formula, it is axiomatic among venture capitalists and private-equity firms that reduced uncertainty and improved opportunities within a stable ecosystem provide opportunities to derive a higher return on their investments.

The result of these two general tradeoffs in last-mile engineering economics is that, for any given broadband speed, the best network options for the last mile for regions with low population density will not be the same as those of high-density areas. Accordingly, this Part describes high-level broadband roadmaps across three general bands of population density in which the last-mile networks will be deployed: rural, suburban, and urban. The broadband roadmap will classify the best fit of a general category of last-mile options by cost and speed for each of these population density categories.

With this approach in mind, Figure 2 shows the best-fit deployment zones of the different last-mile technology alternatives for different broadband access speeds and population densities within emerging countries, given current solutions over the short term.

83. *Id.* at 44 fig.1. (showing the extent to which emerging countries are lagging behind developing countries in the coverage and speed of broadband networks).

Figure 2. "Best-Fit" Deployment Zones in Emerging Countries



This chart suggests the following general observations that will drive the development of the broadband roadmaps in emerging countries:

- *Wireline versus Wireless*. Wireline networks usually provide higher broadband speed access than wireless alternatives. This may not always be the case when, for example, there is a bottleneck or a slow-speed connection between the backbone and access networks due to specialized circumstances, when the wireless platform has the benefit of using an exceptionally large amount of spectrum (e.g., the five GHz unlicensed band for Wi-Fi), or when the condition of the wireline network is very poor (e.g., causing broadband speeds from ADSL to be comparable or less than wireless alternatives). In general, however, the intrinsic capability of the wireline network exceeds that of the wireless alternative.
- *Mobility versus Portability*. For at least the next five to ten years, wireless networks supporting mobility management will deliver lower speeds than wireless networks that support portability alone. The cost to implement mobility management is high enough to restrict the amount of bandwidth deployed with this additional switching capacity and capability to hand off active connections between antennas. Within the next five years, some portable wireless technologies such as Wi-Fi will likely

incorporate a mobile capability into wireless platforms, thus moderating and eventually eliminating this differentiation.[84]

- *Emerging Countries versus Developed Countries*. The main difference in this chart versus one that would apply to developed countries is the smaller best fit of legacy wireline technologies. In developed countries, existing telephone and cable networks provide the most viable broadband solution for a broader swath of population densities due to the incremental economics that can be realized in the legacy networks by gradually deploying more fiber closer to the end user. For emerging countries, the lack of existing legacy network coverage is addressed through the emergence of new portable wireless platforms such as Wi-Fi or satellite.

The best-fit deployment zones in Figure 2 show the current capabilities and costs of last-mile network technology alternatives. Over time, the best-fit deployment zones will change due to innovation and network evolution (i.e., the incremental changes made to the network infrastructure). We attempt to capture the impact of these longer-term trends over time in Figure 3. Technological innovations within each last-mile category will tend to increase the speed of broadband access and lower the cost of network equipment (making the approach more viable for lower levels of population density). Network evolution will likewise have a similar impact over time. Making an incremental investment by adding new technologies to the network over time costs much less than completely rebuilding the network, thus lowering the network cost per user. This lowered cost, in turn, permits a higher broadband access speed and/or more viable coverage of the network in regions with lower population density. Thus, for example, continuing decreases in the cost of 3G (IMT-2000)[85] network equipment will allow 3G mobile data networks to be deployed with higher broadband speed into areas of lower population density.

84. *See, e.g.*, Kevin C. Tofel, *Apple iOS 7 Supports Wi-Fi Hotspot 2.0 for Next-Gen Network Roaming*, GIGAOM (June 11, 2013, 8:32 AM), http://gigaom.com/2013/06/11/apple-ios-7-supports-wi-fi-hotspot-2-0-for-next-gen-network-roaming/ (describing a seamless, hands-free transition between Wi-Fi hotspots for iPhone iOS 7 users).

85. *See supra* Table 3.

Figure 3. Long-Term Trends

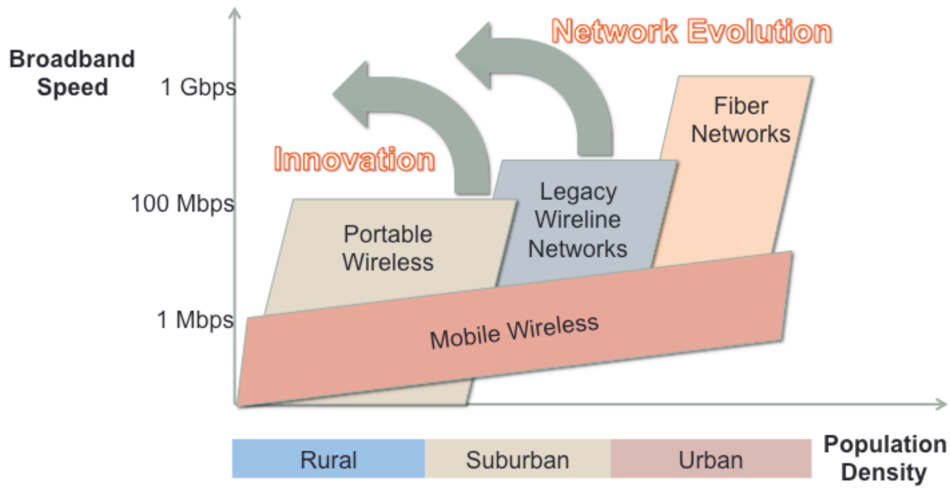
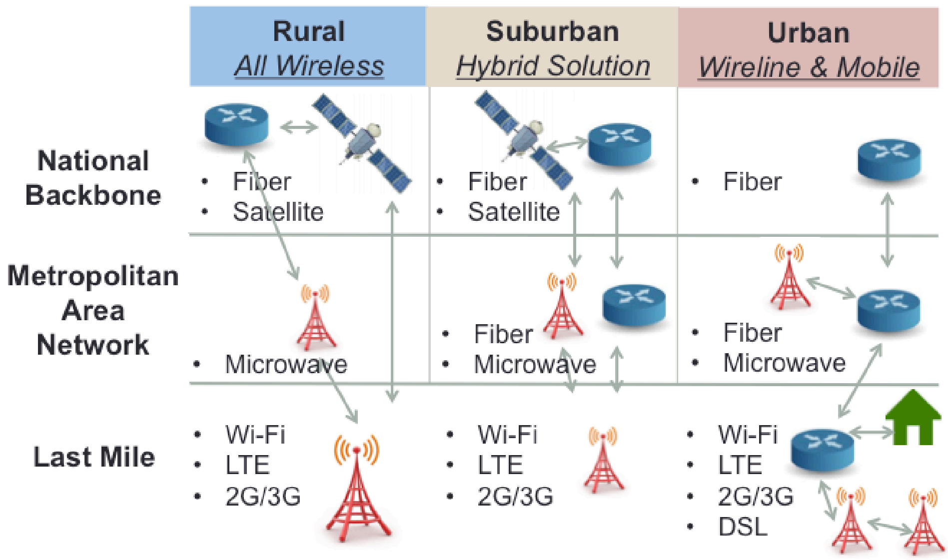


Figure 4 shows a simplified view of the current deployment of network infrastructure in emerging countries across the range of population densities from rural to urban given the framework of last-mile options introduced in the last section, along with straightforward assumptions regarding the options for network technologies deployed in the metropolitan area network and national backbone network segments (e.g., fiber, satellite, or microwave). This chart reflects the previously described view of network economics. In other words, if any network is present at all in the rural areas, then it is wireless—enabling either mobile or portable use. In urban areas, wireline networks are common since the additional cost is justified, as are the wireless networks that support mobile and portable applications. The suburban region approach is a hybrid solution that transitions from the rural (predominantly wireless) approach to the urban (predominantly wireline) approach, as the proximity of any given area grows closer to urban areas.

Figure 4. Differences in Current Broadband Deployment Approaches by Population Density



However, the current broadband deployment point of view described in Figure 4 may not be the best network-technology fit for the circumstances found in emerging countries. A significant unknown factor is how the regulatory or legislative environment of a particular country may impact the build-out of the network infrastructure by favoring particular technologies.[86] Nevertheless, we can apply this broadband framework in order to forecast broadband network evolution based on the long-term trends of lower costs and higher speeds for different levels of population density assuming a rational deployment of technology.

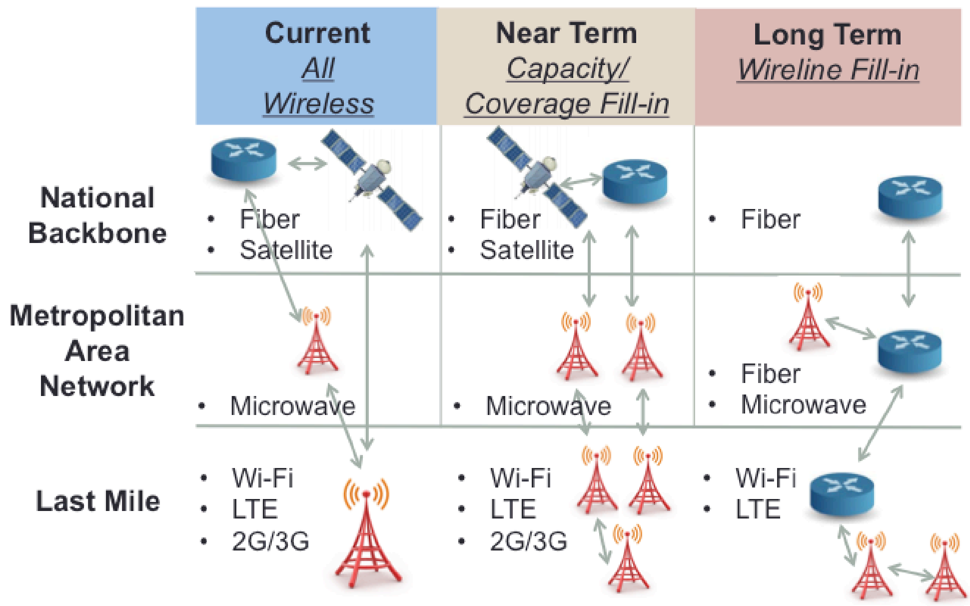
Figures 5–7 illustrate the broadband roadmap for rural, suburban, and urban areas, respectively. These roadmaps capture the network deployment scenarios for current, near term (three to five years in the future), and long term (five to fifteen years in the future) timeframes. The broadband roadmaps in these Figures all suggest a trend from wireless to wireline (fiber) over time, beginning with capacity/coverage fill-in of current wireless systems followed by wireline fiber network fill-in where the cost is justified. The higher the population density, the sooner would be the deployment of fiber systems into the area.[87] This is not to suggest that wireline systems will

86. For further discussion, see *infra* Part V.

87. As an example of the extent to which fiber has been deployed in emerging countries, O3B Networks estimates that as of 2011, only 30.8% of Africans are currently

fully replace all wireless systems in an area—only that the increasing broadband traffic over time will support building wireline networks to connect the wireless systems.

Figure 5. Rural Broadband Roadmap



within twenty-five kilometers of a terrestrial fiber node, and 47.7% are within fifty kilometers of a fiber node. Future "planned" fiber deployment could increase these figures to 46.1% and 69.9%, respectively. O3B NETWORKS, WHERE FIBER FEARS TO TRENCH 6 (2014), *available at* http://www.o3bnetworks.com/media/40977/white paper_where fiber fears to trench.pdf.

Figure 6. Suburban Broadband Roadmap

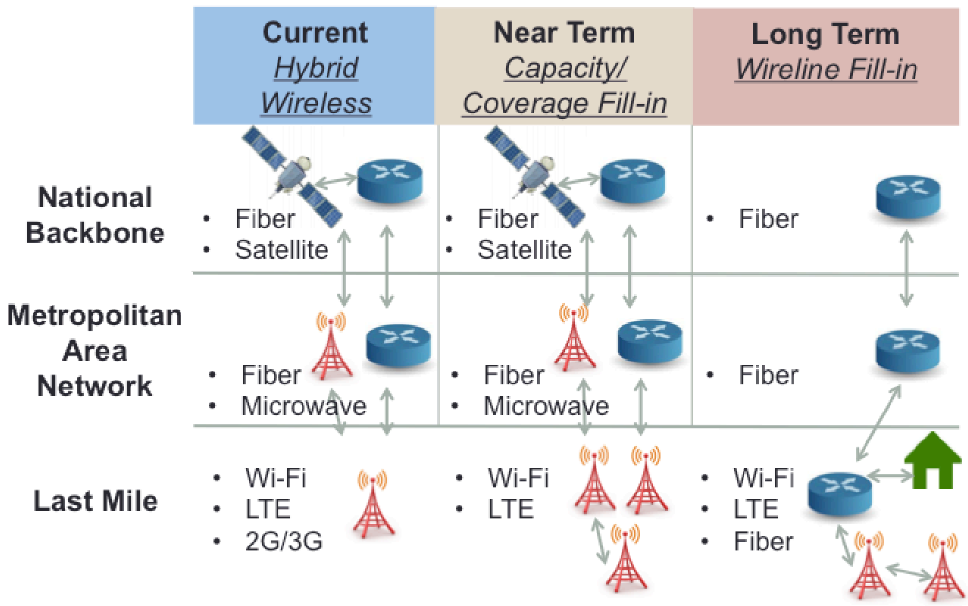
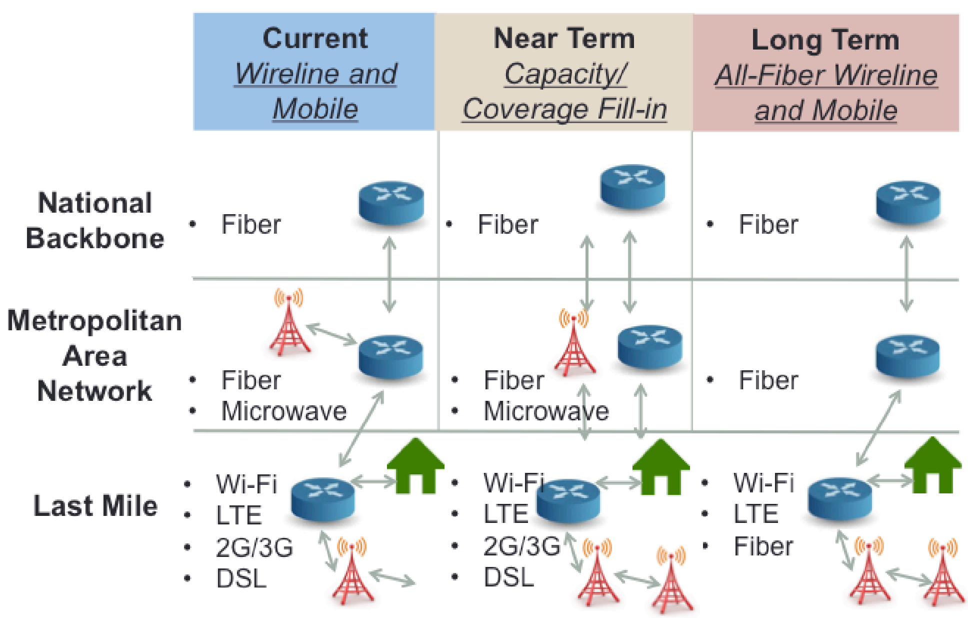


Figure 7. Urban Broadband Roadmap



In concluding this Part, we note that the broadband roadmaps, described above, make clear that wireless technologies are likely to play a prominent role as the initial solution for the last mile of the broadband network in currently unserved, rural areas of emerging countries.[88] Wireless access networks—whether by satellite or macrocell—cost less and can be deployed more rapidly, presuming there is sufficient spectrum—both licensed and unlicensed—available to offer broadband data services.[89] The deployment of mobile networks as the first broadband system in a region, called "mobile leapfrogging" by some researchers, is not without some concerns with regard to its adequacy as a broadband solution.[90] To date, mobile phone use has not served as a substitute for Internet access, often due to the fact that most mobile "feature phones" do not support broadband data.[91] Nevertheless, the usually significantly lower fixed costs of wireless networks over wireline options in rural and currently unserved areas will favor this outcome.[92]

V. POLICIES TO HELP INSTITUTE BROADBAND DEPLOYMENT

Unfortunately, the largest barriers to the rapid adoption and deployment of broadband roadmaps in emerging countries are often erected by government regulatory policies that inhibit Internet growth rather than promote it.[93] In this Part, we describe a five-point policy approach to help

88. We are not the first to hold this view. *See, e.g.*, Eric Brewer et al., *The Case for Technology in Developing Regions*, COMPUTER, June 2005, at 25, 26 ("For rural areas, a wireless infrastructure appears to be the first kind of infrastructure that is affordable."); F. Simba et al., *Broadband Access Technologies for Rural Connectivity in Developing Countries*, 2 INT'L J. RES. & REVS. COMPUTER SCI. 312 (2011).

89. Mukesh Kumar, Wireless Versus Wireline—Competing Broadband Access Technologies 1 (Sept. 1, 2012) (unpublished manuscript), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2305028 ("Compared to wireless access technologies, wireline access technologies give better performance in terms of bandwidth as well as quality of service but they lack ubiquity and affordability.").

90. *See* Philip Napoli & Jonathan Obar, *Mobile Leapfrogging and Digital Divide Policy*, NEW AM. FOUND. (Apr. 1, 2013), http://newamerica.net/publications/policy/mobile_leapfrogging_and_digital_divide_policy/ (noting that mobile smartphones are not yet acting as the functional equivalents to personal computers and the explaining limitations this poses in the attributes of applications and services available through Internet access).

91. *See* ARABA SEY ET AL., CONNECTING PEOPLE FOR DEVELOPMENT: WHY PUBLIC ACCESS ICTS MATTER 81 (2013), *available at* http://tascha.uw.edu/publications/connecting-people-for-development/.

92. *See* Kumar, *supra* note 89, at 1.

93. *See, e.g.*, SCHUMAN & KENDE, *supra* note 51, at 44–45 (contrasting African countries with strong policies of promoting Internet development versus those countries where failed public leadership has stalled increased connectivity).

enable the deployment of broadband roadmaps like those described above, despite the challenging business conditions that exist in unserved regions: (1) Shared Infrastructure, (2) Spectrum Policy, (3) Access and Interconnection, (4) Innovation and Stimulation of Demand for Broadband, and (5) Collaboration.

Increased deployment and adoption of broadband Internet access will produce demonstrable social and economic benefits for individual users and their national economies. Part IV described some of the technologies and business ideas that will increase usage of the Internet in difficult-to-serve areas. However, even well-reasoned broadband roadmaps cannot succeed if the regulatory and policy environment does not encourage the rapid deployment of broadband networks by as many service providers as the market can accommodate.

Breaking this technical, economic, and policy logjam will require a focused effort on the part of government, private industry, academic research institutions, and nonprofit organizations. While we do not presume to know all of the policy changes ultimately needed for successful broadband deployment—nor do we make specific policy recommendations—we have identified these five general areas that need specific, proactive policies to achieve broadband rollout objectives. The following Sections describe each of these policy goals in more depth

A. SHARED INFRASTRUCTURE

Perhaps the most critical area of focus (and the opportunity for greatest improvement) is the ability and willingness of telecommunications, power service, and other infrastructure providers to share infrastructure in building out broadband platforms. Shared infrastructure is critical as a policy objective because of the high cost of deploying broadband infrastructure, particularly in the last mile. Such costs can be spread across more utility services to the extent that existing facilities can be leveraged and ongoing infrastructure improvements can be coordinated.

Importantly, while this Article posits the availability of shared infrastructure as crucial to the effective and rapid deployment of broadband, policies should encourage—but not mandate—sharing because requirements can sometimes distort markets (e.g., by creating a free-rider problem or by imposing significant oversight requirements on agencies that may not be equipped to monitor effectively). The way to incentivize the sharing of infrastructure will vary from market to market, depending on factors like (1) the availability of infrastructure from incumbents or the state; (2) the nature of how much and what kind of infrastructure needs to be deployed (e.g., rural mountainous environments bear different kinds of challenges than rural desert environments); and (3) the ability of regulators to use competition law and similar mechanisms as a way to minimize abuses by large players down the road.

Shared infrastructure models in developed countries have often focused disproportionately upon unbundling (i.e., splitting up) the local loops of existing telephone networks. These unbundling efforts have been implemented in mature markets like the United States and Europe where incumbents have developed infrastructure over a period of several decades and where regulatory action was required to enable competition to enter the market and provide services. However, emerging countries may not always have a robust, legacy telephone network to serve as a platform for open access. Thus, within the context of our broadband roadmaps presented in Part IV, shared infrastructure applies to the notion of joint deployment of the wireless networks with electricity, roads, energy pipelines, or other core infrastructure.[94]

Thus, it is important to keep in mind that in emerging markets the incentives for investment may be more important at the outset than new requirements on the sharing of incumbent infrastructure. Such incentives might include tax incentives, lower licensing hurdles in exchange for build-out commitments, and tools. This is particularly the case in markets where competition policies are in place that could be used to address abnormalities at a later stage as the infrastructure is deployed. For example, it is possible that a new entrant may build out a series of utility poles, dig trenches, and install wireless towers in order to reach a new rural market. Although it could be attractive for competition in the future to require that such new installations must be shared with other entrants, it is also quite possible that such investments may never occur if the investors cannot plan for a certain kind of return on their investments. For this reason, competition law or strong regulatory oversight can be used at a later point to evaluate how any single actor is behaving in the market and reduce abuses by the actor.

As previously discussed, deployment of new telecommunications infrastructure often acts as the catalyst for introducing the electrical grid in rural areas.[95] The joint deployment of this infrastructure provides critical cost-sharing opportunities that help speed the deployment and development of broadband systems. Additionally, the establishment of new infrastructure in the utility grid (where often none exists) demonstrates the potential for the

94. *See generally* Conference on Infrastructure Sharing Models and Practices, held by ITU Centres of Excellence for the Asia-Pacific Region (May 20–23, 2013), *available at* http://academy.itu.int/moodle/course/view.php?id=573.

95. *See supra* Subsection II.A.1.

broadband sector to provide opportunities for economic development in many other industries. The availability of power and a new electric grid does just that by encouraging entire villages and regions to operate myriad businesses that cannot exist without electricity. It therefore can be a significant disincentive if the new infrastructure projects are saddled at the outset with complex mandatory sharing requirements, particularly if it is the aspiration of countries to attract foreign investment and to give the investors the ability to amortize their investment over time. ITU studies provide an overview of several practical measures that minimize broadband project costs, with a focus on taking advantage of the construction of shared infrastructure with other basic utilities.[96]

Within this point of view, a key opportunity for infrastructure sharing within the broadband roadmaps is the extension of fiber between high-density population centers. From a practical standpoint, policies that promote and accelerate connecting municipalities with fiber could help regions move forward in their broadband implementation.[97] Many emerging countries have already recognized the value of this approach. For example, Colombia has been installing thousands of kilometers of fiber to increase the number of connected municipalities from two hundred in 2010 to 1078 (96% of the national territory) in 2014.[98]

Government encouragement for a "dig once" approach—meaning all the infrastructure providers serving a specific area cooperate to install common infrastructure such as trenches, conduit, and utility poles—can be another policy tool to facilitate deployment of shared infrastructure. Dig-once approaches have reduced network installation costs by 25–33% in urban areas and roughly 16% in rural areas.[99]

B. SPECTRUM POLICY

As a general rule, governments will need to maximize the amount of spectrum available for mobile and portable Internet access to support wireless broadband platform deployments. While a full review of spectrum

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96. *See* MATT YARDLEY, DEVELOPING SUCCESSFUL PUBLIC-PRIVATE PARTNERSHIPS TO FOSTER INVESTMENT IN UNIVERSAL BROADBAND NETWORKS 39–42 (2012), *available at* http://www.itu.int/ITU-D/treg/Events/Seminars/GSR/GSR12/documents/GSR12_BBReport_Yardley_PPP_7.pdf.

97. *See* Diego Molano Vega, *Colombia's Digital Agenda: Successes and the Challenges Ahead*, *in* GLOBAL INFORMATION TECHNOLOGY REPORT, *supra* note 81, at 111, 112.

98. *See id.*

99. *See* U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-12-687R, PLANNING AND FLEXIBILITY ARE KEY TO EFFECTIVELY DEPLOYING BROADBAND CONDUIT THROUGH FEDERAL HIGHWAY PROJECTS 5 (2012).

policy in emerging countries is beyond the scope of this Article, it is worth reemphasizing that there is not a shortage of spectrum in unserved areas but rather a shortage of effective spectrum usage as a result of inefficient licensing of the spectrum (e.g., the license-holder is using the spectrum in urban but not suburban or rural areas).[100] Consequently, technologies that facilitate spectrum sharing may be a way to free up additional spectrum from mobile broadband without displacing incumbent users.

An example of spectrum sharing is the reuse of some of the television bands—the Television White Spaces ("TVWS"), which are unused channels in the broadcast television spectrum band. Here, the opportunities for sharing are plentiful, particularly in emerging markets. Google has conducted in-house research to show that some regions of Africa have caches of unused spectrum that exceed that of countries like the United States. For example, this research compared the available spectrum in TVWS in Dakar, Senegal with that available in San Francisco.[101] As can be seen in Figure 8 where the lack of dark shading indicates a larger number of white space channels available, the results show considerable availability in Dakar.[102]

Figure 8. Spectrum Availability in San Francisco, Calif. vs. Dakar, Senegal

Another potential policy for promoting spectrum sharing is "share before use," whereby the licensed primary spectrum holder registers existing base stations in a spectrum database. An entrepreneur, such as a secondary

100. *See e.g.*, US FED. COMMC'NS COMM'N SPECTRUM POLICY TASK FORCE, REPORT OF THE SPECTRUM EFFICIENCY TASK FORCE (2002), *available at* http://www.fcc.gov/sptf/files/SEWGFinalReport_1.pdf.

101. Alan Norman, *More Than 15 African Countries Gather to Explore the Potential of TV White Spaces*, OFFICIAL GOOGLE.ORG BLOG (June 3, 2013, 6:21 PM), http://blog.google.org/2013/06/more-than-15-african-countries-gather.html.

102. *Id.* (containing an original color graphic, where green indicates a larger number of white space channels available).

operator, can use the spectrum database to identify locales it wants to serve to confirm the spectrum is licensed to a primary spectrum holder, but available and not in use. This can often be the case in unserved or underserved, often rural, areas.

Ultimately, the private sector needs to develop technologies to use spectrum that is otherwise locked down on paper.[103] In short, there should be a regulatory framework that enables various kinds of software-defined radio[104] to alleviate the problems that are acute in many markets in which no firm can use spectrum—not because it actually is being used, but instead because the spectrum is administratively occupied. Although there are many ways for this model to work, in one scenario, the secondary operator could register its base stations in a spectrum database, providing service to the unserved or underserved community, but it must then vacate the spectrum if the primary licensed spectrum holder chooses to deploy service. This type of share-before-use policy provides flexibility for a smaller, entrepreneurial secondary operator to provide service where there may otherwise be none and often serves to prime the area for the primary operator to eventually make the business justification to deploy service.[105]

Beyond more effective sharing of licensed spectrum, emerging countries would likely benefit from the freeing up of more unlicensed spectrum for use. Such use has been shown to contribute considerable value to the overall broadband ecosystem.[106]

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103. *See, e.g.*, Steven Song, *War of the Worlds in Spectrum Licensing*, TECHCENTRAL (Oct. 28, 2013), http://www.techcentral.co.za/war-of-the-worlds-in-spectrum-licensing/44649/ (arguing for the creation of "something akin to a Creative Commons model for spectrum management that establishes a palette of options for how spectrum might be managed, ranging from mono-ownership, exclusive rights to spectrum, to unlicensed use").

104. Software-defined radio is a radio communication system where components that have been typically implemented in hardware are instead implemented in software.

105. There are many new possibilities with various advances in software-defined radio that can be used to completely change the way that regulators have previously thought about spectrum management. For a discussion of such advances, see e.g., Patrick S. Ryan, *Wireless Communications and Computing at a Crossroads: New Paradigms and Their Impact on Theories Governing the Public's Right to Spectrum Access*, 3 J. ON TELECOMM. & HIGH TECH. L. 239 (2005); Patrick S. Ryan, *Application of the Public-Trust Doctrine and Principles of Natural Resource Management to Electromagnetic Spectrum*, 10 MICH. TELECOMM. & TECH. L. REV. 285 (2004).

106. *See* PAUL MILGROM, JONATHAN LEVIN & ASSAF EILAT, THE CASE FOR UNLICENSED SPECTRUM 2 (2011), *available at* http://www.stanford.edu/~jdlevin/Papers/UnlicensedSpectrum.pdf (noting a Microsoft study that estimated uses of unlicensed spectrum to be worth sixteen to thirty-seven billion dollars per year).

C. ACCESS AND INTERCONNECTION[107]

Broadband deployment requires local content and the ability of all Internet Service Providers ("ISPs") to interconnect efficiently. This is where the role of Internet Exchange Points ("IXPs")—physical infrastructure whereby ISPs can exchange traffic between their networks—becomes critical, and it is important to have policies in place that favor the development of an IXP market, even at the risk of upsetting the incumbent provider who may not share the same interests in promoting IXP infrastructure.[108]

In order to understand what an IXP is, we will first distinguish between two basic aspects of Internet connectivity: *transit* and *peering*. The term transit refers to the wholesale product purchased by ISPs from large telecommunications carriers to reach networks with which they do not have peering relationships. Consumers purchase retail transit from an ISP, such as a local cable company or telephone company, in order to connect their computers to the Internet. With the exception of a small number of very large multinational network operators, most ISPs need at least one transit provider to ensure they (and their customers) can reach the entire Internet.

The term peering, on the other hand, refers to the means by which ISPs interconnect their networks. These interconnections allow ISPs to exchange traffic between networks so customers of one network can reach customers on another network. For example, assume a customer obtains transit from the telephone company and that customer's friend buys transit from the cable company. The traffic from a peer-to-peer video chat between the two individuals would need to pass between those networks via direct interconnection or intermediate networks, which would in turn connect to other networks. A robust regional IXP ecosystem would mean that the traffic from the aforementioned video chat would stay entirely within the region instead of "tromboning" (i.e., using international connections for domestic traffic rather than connecting to domestic ISPs directly, thus routing away from the region and back).[109] The advantages of peering are many. In addition to reducing costs by keeping traffic local, ISPs are able to establish more deterministic traffic delivery to customers, as well as improve performance and reliability.

107. The authors are grateful for the research and writing assistance provided by Jason Gerson for this Section. *See* Gerson & Ryan, *supra* note 54.

108. For a fuller definition of IXPs, see *What Is an IXP?*, EUR. INTERNET EXCHANGE ASS'N, https://www.euro-ix.net/what-is-an-ixp/ (last visited Apr. 4, 2014).

109. *See* Gerson & Ryan, *supra* note 54, at 6–7.

IXPs can help increase the efficiency of Internet traffic exchange and create a win-win for a local economy. However, it is also important to recognize that IXPs are not a panacea for every market. Below are illustrations of two situations at opposite ends of the spectrum that present unique challenges:

1. *Situation One: Markets with Only a Few ISPs*

If most of Internet traffic is exchanged among a small set of operators (e.g., two or three ISPs), an IXP is unlikely to succeed because there is little need for a neutral exchange. In these cases, the ISPs likely know each other and can work out traffic exchanges with each other. Here, regulatory oversight might serve only to ensure there is no collusion or anticompetitive behavior, as can sometimes occur in tight oligopolistic markets. In Nigeria, for instance, a less open market with little ISP buy-in initially constrained Nigeria's Ibadan Internet Exchange.[110]

2. *Situation Two: Markets with Many ISPs That Do Not Get Along*

In some cases, ISPs do not trust each other and will not reach an agreement. Competition can be fierce, such that no nongovernmental third party can remedy the situation. In cases where impasses arise, it might make more sense for regulators to offer dispute resolution and to impose contract terms—as is done when competing companies in the United States cannot reach terms for access to shared utility poles, ducts, and conduits.

There may not be an ideal ecosystem for an IXP since market, cultural, and legal conditions can vary greatly. However, a more straightforward case is one where ISPs have generally balanced traffic flows between networks, and there are inexpensive ways to peer. In such instances, ISPs often agree to settlement-free peering wherein each network covers the cost of its connection and equipment, and no payment is exchanged. Further, IXPs reduce the cost of peering and increase value by creating an environment where multiple networks are present and capacity is shared.[111]

The question remains where ISPs should conduct their peering. Peering could happen directly among ISPs at their facilities, but doing so can be expensive, especially if there are numerous networks, each with a dedicated connection. This is one reason why most IXPs provide a shared switch that allows ISPs to exchange traffic with multiple other networks via a single connection, thus enabling an ISP to access many networks via one shared

110. *See IXPN History*, IXPN, http://ixp.net.ng/history/ (last visited Apr. 1, 2014) (detailing the history of IXPs in Nigeria).

111. *See* WILLIAM B. NORTON, THE INTERNET PEERING PLAYBOOK 98 (2014).

fabric. Put another way, IXPs offer ISPs, large and small, a common place to meet and exchange traffic in the manner that works best for any given network.

There is no single way to govern IXPs, and governance philosophies vary around the world. While each model serves a specific marketplace and has its own advantages and disadvantages, in the end no one model fits every ecosystem. While there is no single, unified management model, there are regional trends, as shown in Table 7.

Table 7. IXP Models, Their Advantages and Disadvantages, and Their Regions of Predominance

IXP Model	Advantages	Disadvantages	Regions Utilizing Model
Voluntary IXPs	Good stepping stone to later development, easy to set up, low cost and low maintenance	More limited functional potential, unlikely to have established leadership	Emerging countries
Commercial IXPs	Able to afford expenses, able to expand IXP reach easily	May compete with ISPs, difficult to retain neutrality	United States
Cooperatives	Sensitivity to member needs	Possibility of weak leadership	Europe
Managed Non-profits	Customers cannot veto IXP policies	A strong non-profit institution needs to provide IXP oversight	Europe

To help provide guidance to budding IXPs and policymakers wishing to understand them, Michael Kende and Charles Hurpy have suggested that IXPs should look to the organizational models of top-tier IXPs, such as LINX.[112] This suggestion is a good start, but even top-tier models continue to evolve. In some regions, it might make sense for all members to have voting shares in the IXP, particularly if doing so would equalize the balance of power. However, if an IXP allowing voting memberships does not cater equally to all parties, some ISP members may terminate their memberships, which could significantly reduce the value of the exchange.

112. *See* MICHAEL KENDE & CHARLES HURPY, ASSESSMENT OF THE IMPACT OF INTERNET EXCHANGE POINTS—EMPIRICAL STUDY OF KENYA AND NIGERIA 1–12, 21–48 (2012), *available at* http://www.internetsociety.org/ixpimpact; *see also* LINX, https://www.linx.net/ (last visited Apr. 4, 2014).

D. INNOVATION AND STIMULATION OF DEMAND FOR BROADBAND

While the broadband roadmap for emerging countries is not set in stone, the roadmaps described in Part IV can be used to start a conversation about what may be possible based on the current understanding of publicly available technology. Pushing the state of the art in broadband deployment will require policies that offer incentives for entrepreneurs, governments, and the public at large to use broadband and showcase its importance.

Overall, it is generally accepted that the best policies for achieving more innovation and entrepreneurship are associated with liberalized markets that permit private firms substantial flexibility in meeting market demand.[113] This message is already well understood in emerging countries striving to improve the investment climate for starting new telecommunications businesses. Despite good intentions, however, many markets in emerging countries remain subject to entry barriers and to anticompetitive behavior by a few dominant players.[114] Establishing a market for broadband access that flourishes with innovation and entrepreneurial activity will require policies that encourage open entry through removal of anticompetitive regulations along with the effective enforcement of these rules.

Beyond market liberalization of broadband transport, there are a number of other areas where regulatory policies may encourage broadband application development, demand for broadband, and customer equipment:

1. *Broadband Application Development*

A robust market for broadband applications and services is the lifeblood of the Internet ecosystem. Content establishes consumer and business demand for broadband systems. Governments need to ensure that their public policies establish an open marketplace for applications in order to allow the most efficient development of compelling applications, both on a local and global basis. Broadband networks will also be a critical information channel for e-government applications and services. The ITU provides a number of specific initiatives, describing an e-government application in India, e-health in Malawi, and e-learning in Africa.[115]

113. *See* Markus Kitzmuller & Martha Martinez Licetti, *Competition Policy: Encouraging Thriving Markets for Development*, WORLD BANK GROUP: VIEWPOINT, Sept. 2012, at 1–2, https://www.wbginvestmentclimate.org/advisory-services/cross-cutting-issues/competition-policy/loader.cfm?csModule=security/getfile&pageid=42573.

114. *Id.* at 4–6.

115. *See* YARDLEY, *supra* note 96, at 44–46.

2. *Promoting Demand for Broadband*

The challenging economics of last-mile networks in rural areas that are currently unserved will require the creation of demand for broadband. Due to the fixed costs of these networks, demand aggregation and stimulation schemes will be important for broadband project success.[116] These schemes are needed in order to jumpstart the business model by getting higher penetration rates soon after network deployment to offset the upfront costs. Innovative service packages and network registration approaches—customized to address local circumstances—will be integral to implementing a sound business model. Regulatory policies need to recognize the benefits of such schemes early in the broadband deployment cycle to achieve a larger foothold upon which further expansion of the network can be supported.

This regulatory flexibility could lead to broadband deployments initially in currently unserved rural areas with concentrations of commercial businesses and residential homes. These early deployments can then foster innovation, establish the Internet platform for new companies to create new products and services, and otherwise stimulate new job creation and economic growth.

3. *Customer Equipment*

Programs to subsidize and simplify the rollout of broadband customer equipment are also likely to complement the demand aggregation and creation strategies noted above. Service providers often bundle subscription packages—a mobile smartphone or a home gateway—with subsidized customer equipment. Given the lower cost of entry provided by the equipment subsidy, this approach can help to create demand for broadband access.

E. COLLABORATION AMONG THE PLAYERS

Gaining ground on broadband deployment in emerging countries will require extraordinary focus and cooperation among policymakers (international, federal, state, and local), service providers, content providers, equipment vendors, and anchor institutions such as universities and hospitals. Collaboration on the scale required for success in emerging countries could take a number of different forms in order to achieve a successful outcome.

First, a public-private partnership ("PPP") is a common vehicle by which emerging countries have implemented substantial projects to increase the

116. *Id.* at 36.

deployment of broadband systems. While an extensive review of different PPP models and approaches is beyond the scope of this Article, the flexibility of the approach to meet regional objectives and circumstances based on either private- or public-sector investment models has produced promising results in numerous settings.[117] Research has been conducted by the ITU to identify the best practices of successful PPPs in order to promote replication of this collaborative model in different settings.[118] Notably, the ITU report observes that the sustainability of a project depends more on the business model and expertise of the project partners than on the choice of technology.[119] Stated another way, public policy must permit the formation of broadband-focused companies that can develop and implement feasible broadband roadmaps.

Second, another key ingredient to collaboration will be stakeholder partnerships between the broadband service providers and significant broadband consumers that can serve as anchor tenants, or the first and leading tenants. Whether the customers are educational institutions, health providers, or key industrial segments such as oil and gas, each region will likely present the opportunity to construct broadband systems for anchor tenants. These systems can then be expanded incrementally at very low cost to offer consumer broadband services as well.

Third, while private-sector and anchor-tenant participation is essential, proactive and clearly defined government leadership and planning is also critical. Indeed, a recent report from the ITU and Cisco concluded that countries that adopt a broadband plan are associated, on average, with 2.5% higher fixed broadband penetration and 7.4% higher mobile broadband penetration.[120] Successful national broadband plans provide the blueprint for the development and evolution of the broadband market within a country. For example, as a first step in moving forward with its plans to implement a broadband economy, Rwanda established a regulatory framework that provided the necessary institutional, legal, and regulatory leadership to liberalize the telecommunications industry and reduce entry barriers to the telecommunications markets.[121]

117. *See id.* at 42–49.

118. *Id.* at 50–53.

119. *Id.* at 15.

120. *See* PLANNING FOR PROGRESS, *supra* note 58, at 7.

121. *See* Alex Ntale, Atsushi Yamanaka & Didier Nkurikiyimfura, *The Metamorphosis to a Knowledge-Based Society: Rwanda*, *in* GLOBAL INFORMATION TECHNOLOGY REPORT, *supra* note 81, at 119, 119–20.

Fourth, beyond leadership, it is important for the government to also facilitate access to any public assets and infrastructure that may exist in the area. The list of such assets could include fiber, radio towers, rights-of-way, pole attachments, utility conduits, and other community assets. The advantages presented through municipal cooperation can be significant. As of writing, Google Fiber has launched projects in Kansas City, Provo, and Austin, with plans for additional cities as well.[122] One of the benefits of these projects is the example they provide of how stronger cooperation with municipalities can yield positive results. The model still relies upon entrepreneurs, but government acts as a partner for innovation rather than as a roadblock.

Finally, information sharing, particularly among emerging countries, is a key collaboration tool for governments. As countries experiment with broadband technologies and the policies that enable them, they can embrace both failures and successes to help determine how to best gain ground on broadband deployment. The private sector and civil society also have a role to play in facilitating information sharing. The Alliance for Affordable Internet, a PPP that runs as a project within the World Wide Web Foundation, aims to promote best practices regarding policies and regulations that help drive down the cost of Internet access in emerging countries.[123] As part of its mandate, the Alliance conducts research and highlights case studies that provide an evidence base for governments to enact best practices.[124]

VI. CONCLUSION

Last-mile broadband networks are the most challenging network segment to tackle because of the high-cost barriers to deployment and significant, long-standing regional and global policy hurdles.[125] No single, one-size-fits-all technology can address the broad range of coverage and bandwidth concerns in developing countries. Rather, connecting the unserved and underserved users who make up the next five billion will require implementation of various last-mile broadband technologies.

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122. *Cities and Plans*, GOOGLE FIBER, https://fiber.google.com/cities/ (last visited Apr. 4, 2014).

123. *Vision and Strategy*, ALLIANCE FOR AFFORDABLE INTERNET, https://a4ai.org/visionand-strategy (last visited Feb. 8, 2014).

124. *See Policy & Regulatory Best Practices*, ALLIANCE FOR AFFORDABLE INTERNET (Sept. 6, 2013), http://a4ai.org/wp-content/uploads/2013/09/A4AI-Best-Practices-launch1.pdf.

125. *See supra* Part IV.

While technologies and implementation strategies will vary, establishing a set of standard policy guidelines has the potential to increase the success of most last-mile deployment efforts. In particular, consensus-based proactive policies are needed to promote shared infrastructure, liberalize spectrum, facilitate access and interconnection through IXPs, create ecosystem-wide demand for broadband (and associated innovation, entrepreneurship, and technical experimentation), and encourage collaboration and discussion of best practices within the geographical regions in question.

We believe such policies can and will garner increasing global attention as regulators, policymakers, and entrepreneurs come to fully understand (1) the importance of building out this last-mile network as a viable means of countering the digital divide around the globe and (2) the worldwide socioeconomic implications of neglecting to resolve the deployment problems faced in building out this part of the network. Hopefully, the presented framework can help these regulators, policymakers, and entrepreneurs engage in a healthy debate on key next-five-billion Internet deployment issues, as well as help to facilitate the prompt and efficient deployment of the broadband infrastructure required to increase Internet penetration in the emerging countries that need it the most.