Low-cost information technology in developing countries: current opportunities and emerging possibilities ☆

Jeffrey James*

Tilburg University, P.O. Box 90153, 5000 Tilburg, LE, The Netherlands

Received 1 December 2000; received in revised form 16 March 2001; accepted 30 May 2001

Abstract

As its point of departure, this paper takes the view that if the digital divide between rich and poor countries is to be diminished on any significant scale, a wide range of complementary low-cost versions of information technologies will be needed. Since the available knowledge about these technologies is highly fragmented and difficult to access, however, we seek in this paper to provide policymakers not only with a description of some of the more important low-cost information technologies that are already in use, but also with an indication of where such technologies are likely to emerge in the near future. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Information technology; Digital divide; Technical change; Policy; India

Introduction

There is general agreement in the international development community about the need to lessen the strikingly differential extent to which rich and poor countries are enjoying the benefits of information technology, a differential that is often referred to as the digital divide (James, 2001) (some authors argue, moreover, that this already deep divide is growing rather than diminishing over time, an assertion, which if correct, would have disturbing implications for the trend of income inequality between rich and poor countries[1]). There is also considerable support for the view that if the digital divide is to be diminished to any significant degree, the countervailing policy package will need to incorporate low-cost versions of information technology, rather than

---

☆ This paper draws in part on James (2001). I am greatly indebted to Mike Jensen for his comments.
*Tel.: +31-13-466-9111; fax: +31-13-466-3019.
E-mail address: m.j.james@kub.nl (J. James).
[1] For the most recent and extensive study of this issue see Rodriguez and Wilson (2000).

products designed for the higher average incomes prevailing in the developed countries (although, of course, there are many other requirements that will also have to be met with). This policy requirement was clearly recognized, for example, in the summary report of the International Millennium Conference on information technology and development held in India in 2000.[2]

In particular, the report recognizes that,

> while there have been very significant advances in telecom-related science in recent decades, most of these in developed countries have focussed on providing better services and greater bandwidth to the user at a constant cost which is affordable to most in these countries. The requirement in developing countries is, however, significantly different: to provide lower-cost basic access with a reasonable basket of important services such as Internet and voice communication. All the known techniques need to be harnessed to reduce the cost of telecom infrastructure in developing countries. …Such an endeavour alone can make telecom and Internet services widely affordable in the developing countries.[3]

To where, however, should policy makers in developing countries actually turn in order to find such technologies? Ideally, of course, these and other interested actors would be able to turn to a dedicated information site on the World Wide Web that not only included the various types of information technology (such as telecommunications, computers and electronics data transmission) but which was also regularly updated in line with the rapidity of technical change in this area. Unfortunately, however, no such site yet exists and the fragmentary form of information that is available on the World Wide Web is extremely difficult to access with the most common search engines (prone, as they usually are to a number of well-known problems of information retrieval.[4])

Our intention, here, accordingly, is to fill this gap not only by providing policy makers with a description of (and reference to) some of the more important low-cost information technologies that are already in use, but also by indicating where such technologies are likely to emerge in the near future. In this way, by combining existing and emerging innovations, the discussion we feel will be in a form that achieves maximum relevance to policy makers seeking to overcome the digital divide between rich and poor countries (and to some extent, even to policy makers concerned with the divide that exists between rich and poor in the developed countries themselves). More specifically, we shall seek to identify current options and emerging low-cost possibilities in three distinct, though related, forms of information technology, namely, telecommunications, computer hardware and software and electronic modes of communications.

---

[2] In full, the title of the conference was "Commsphere 2000: International Millennium Conference on Affordable Telecom and IT Solutions for Developing Countries", February 28–March 2, 2000, Indian Institute of Technology, Madras, Chennai, India (available at http://www.tenet.res.in).

[3] "Introduction" to the conference cited in the previous footnote.

[4] See, for example, the various articles contained in the Proceedings of the 9th International World Wide Web Conference, Amsterdam, May 15–19, 2000.

Telecommunications

Let us first consider two major innovations that have emerged in India as the result of deliberate research efforts to design telecommunications technologies for the socio-economic conditions prevailing in the rural areas of that country (conditions which require, among other things, that the technologies be available at a lower cost than the comparable alternatives used in most of the developed countries).

The earlier of these two innovations emerged out of the establishment in the mid-1980s of the Indian Centre for Development of Telematics (C-DOT), one of the avowed goals of which was to design "a small rugged [digital] switch which would work in a tropical, non-air-conditioned, environment in small towns and rural areas",[5] in place of the expensive and inefficient electro-mechanical exchanges that were predominant in India prior to the early years of the decade in question. This objective, according to Jhunjhunwala, Ramamurthi, and Gonsalves (nd), "was achieved very successfully, and most of the deployment in small towns and rural areas in India has been (small-scale) C-DOT switches. Today, there are few comparable products available in the world in the cost range (less than Rs. 1500 per line) of C-DOT's rural exchanges."

Measured more precisely in terms of the extent of its adoption and diffusion, the success of this low-cost technology can be gauged by the facts that some 29,000 exchanges have been installed in Indian villages, while exports of the product to more than 22 countries in Africa, Asia and Latin America have already been recorded.

As in this case, the second Indian innovation in low-cost telecommunications technologies was also designed to be affordable to a larger segment of rural society than had thereto been possible. Unlike the former, however, the later innovation was concerned with wireless technology and again unlike the C-DOT case, the goal "was to create an enterprise funded from private sources, which would serve as a model for other telecom equipment ventures" (Stata, 2000). More specifically, the innovation to which I am here referring is a modification of a technology known as wireless local loop (WLL), which was originally conceived in order to supply narrowband telephony services to developing countries that lacked a telephone infrastructure. Wireless local loop is a system that connects subscribers to the public telephone network on the basis of radio signals rather than copper wire for all or part of the connection between the subscriber and the switch. As with the digital switching case, however, WLL has been modified by Indian engineers to make it cheaper and more appropriate to conditions in the rural areas of the "country. Known as CorDect, this technology is said to be

> "all set to usher in a rural telecom revolution in India by paring the cost of rural telephony by well over 50 per cent, besides pegging the maintenance cost including power charges to a bare minimum ….
>
> The project, started in January this year (2000) has wired 50 villages …successfully without using a single centimetre of copper wire …WLL, using the radio communication platform, connects the subscriber to the main exchange by radio waves instead of traditional wire loop ….

---

[5] Jhunjhunwala, A. Toward hundred million Telephones and 25 million Internet connections in India (available at http://www.tenet.res.in). See also the C-DOT page at http://www. cdot.com.

In the case of rural connections, while the cost per connection using conventional technology will be in the range of Rs. 40,000 to well over Rs. 130,000 in the remote villages with rocky terrain, the cost per telephone using the …WLL technology will cost only Rs. 17–18,000 per unit."[6]

CorDect technology has, in fact, already been deployed in two Indian cities, Mumbai and Delhi, while 24 more are scheduled to receive the system in 2001.[7] Again as was the case with the indigenous digital switching technology described above, CorDect has already been quite widely diffused to other parts of the Third World. In particular, licenses have been granted to companies in Singapore, Tunis and Brazil, while systems are operational in Madagascar, Fiji, Kenya, Tunisia, Argentina and Nigeria.

Just as digital switching and wireless technologies can thus be high- or low-cost depending on their design, so also do particular circumstances determine whether satellites represent an appropriate or inappropriate form of communications for developing countries seeking to bridge the digital divide. On the one hand, for example, there are satellite systems that are designed for the minority of people who require more than the twenty per cent coverage of the earth's surface now available through cellular phone networks. In response to this demand, a global satellite telephone network involving 66 low-earth-orbiting satellites was completed in 1998. Predictably, however, access to this ill-fated global system came at a high-cost: 3000 US$ per handset and 1–3 US$ per minute of service.[8] On the other hand, "at the other end of the continuum are very cheap, store-and-forward satellite systems. One such system, Healthsat, uses a single LEO (Low-earth orbiting satellite) to provide communications to health care providers in Africa and other developing regions. The satellite passes over at least once per day; messages can be transmitted in bursts while the satellite is within view before disappearing over the horizon. The system is used for electronic mail and transmission of text, such as articles from medical journals" (Hudson, 1997, p. 30).

The NGO VITA (Volunteers in Technical Assistance) has been involved in such applications of LEOs from the outset and recently (in late 2000), after a decade of expanded development operations in conjunction with its three partners (drawn partly from the private sector) it received authorization from the Federal Communications Commission to operate two low-orbiting satellites that constitute the so-called VITAsat System. This new system is described as being capable of delivering

---

[6] CorDect's pilot WLL project could transform telecom in rural India. *The Financial Express*, November 1, 2000 (available at http://www.tenet.res.in/Press/2001.html).

[7] http:///www.tenet.res.in/cordect/cordect.html. Still other innovations designed in India to bring information to remote rural areas have emerged from research conducted under the auspices of the M.S. Swaminathan Research Fund. The Village Information Project in Pondicherry, for instance, employs a "value addition centre" (where staff located in a central village scan the Internet for useful information) as the hub of a LAN based on Very High Frequency (VHF) radio. The "value addition centre" serves information shops in other villages which are equipped with a Pentium computer and an inkjet printer (available at http://www.mssrf.org). See also the case studies in India reported by Vijayaditya (2000) and Gupta (2000). China is also said to have developed indigenous telecommunications technology, but very little is known about it.

[8] It was partly for these reasons that the satellite project funded by Iridium World Communication proved unsuccessful. See *The Economist*, October 9, 1999.

sustainable, low-cost communication and information services to remote communities having no access to line-based or wireless telephone service. The system uses simple, reliable, store-and-forward e-mail messages relayed to the Internet via non-stationary, low-earth orbiting satellites. Owing to advances in compression technology and software that allow access to web pages using e-mail, the vast resources of the web can be made available anywhere in the world. More than simple connectivity, VITAsat's plans include local skill and organizational capacity building and the development of targeted information content and services designed specifically to meet the needs of small business, local NGOs, educators, health workers, administrators, agricultural extensionists, natural resource managers and other relief and development workers. Additionally, conservation organizations will be able to use the system for inexpensive, remote monitoring of sensitive ecosystems and biodiversity.
VITA's current 2-satellite system has the capacity to serve approximately 2500 remote rural groundstations that will be installed in schools, clinics, community centers, post-offices and local development organizations. Using satellites already in orbit, the system is poised for immediate deployment and is capable of impacting the lives of 2.5 million poor rural households.[9]

Looking rather further into the future one ought, finally, to mention the potential afforded by laser technology for low-cost telecommunications in developing countries. In the form of the so-called "free space laser", for example, the technology uses an infrared band to transmit an optical signal between two points via free space (as opposed, say, to fiber optic cable).[10] One major advantage of this technology is that, unlike microwave systems, it does not require radio permits and licenses (see footnote 10). In terms of its potential for low-cost use in developing countries, laser technology would seem to be most promising when it takes the form of an "open hardware" datalink that connects two personal computers point to point.[11] For one can then costlessly acquire all the necessary documentation and construction guides and the system can be built on the basis of very inexpensive parts. In this form laser technology is "a cheap way how to get over the notorious Last Mile Problem. If you cannot afford a permanent connection into the Internet, you can connect together with your friend and have a permanent connection for half the price. Or third of the price if you connect with one more …and so on" (see footnote 11).

Computers

The quotation cited in the introduction about the role of low-cost information technology in bridging the digital divide, applies no less to computers than it does to the case of telecommunications described in Section Telecommunications. Broadly speaking, the costs of computers used in developing countries can be reduced in two main ways, the first of which is by extending the lives of existing models and the second of which is by designing entirely new products. Again as in the case of telecommunications, some of these measures are already in use while others are yet to emerge.

---

[9] VITAsat: low-cost connectivity for the rural poor (available at http://www.vita.org/leo/summary.htm).
[10] See www.redlinesa.com.
[11] See http://atrey.Karlin.mff.cuni.cz/~clock/twibright/ronja/

Extending the lives of existing computers

In the developed countries, where most of the major technical changes in computers occur, innovations in hardware and software tend to be closely related over time, with much of the causality running from changes in the latter to changes in the former. As a general rule, that is to say, what one finds is a causal relationship in which ever more sophisticated software programs require correspondingly new forms of hardware that are faster, more powerful and exhibit a wider range of design features. As a corollary of this process, computer hardware in those countries tends to become obsolete remarkably quickly. According to a recent study by the US National Safety Council, for example, more than 20 million personal computers became obsolete in the US in 1998 and of these only 11 per cent were recycled and 3 per cent resold or donated (O'Meara, 2000).

Low-income users in developing countries, however, may make different, and often simpler demands on computers and for this group the earlier models thus massively discarded in the US and elsewhere can truly be regarded as "prematurely obsolescent". To this extent, therefore, there is scope for mechanisms which make these otherwise discarded computers available at low-cost to users in the developing countries. Much the same potential exists, one should note, with respect to durable goods such as televisions and video-cassette recorders. In fact, the widespread use of second-hand and black and white televisions appears to have played an important role in the phenomenal expansion of cable television in India, starting almost from scratch in 1992.[12] With regard to computers, Jhunjhunwala (2000) estimates that second-hand Pentium computers could be made available in that country for as little as 125–200 US$, a price at which these products would become accessible to a very much expanded group of potential users.

In South Africa a company called Freecom (formerly Africom), "has been set up to reengineer personal computers. The company will market and sell these computers throughout South Africa and Africa. The target market for these computers is vast and untapped and includes the school market, home users, corporate accounts as well as NGOs, community centres and governmental departments.

The mission of the company is to make appropriate and affordable Information Technology, presently inaccessible to most Africans due to price constraints, more accessible to as wide an audience as possible."[13]

Freecom pays a nominal amount to a US based organization for cleaning the hard drives of the used computers, most of which come from companies, such as General Electric, banks and post offices. Freecom's goal is to supply 16,000 such computers per month at a price of between 300 and 400 US$. Another attempt to supply the demand for the second-hand computers is being made by the recently established "Green PC Inc" whose declared mission, "working with PC manufacturers, leasing companies and other PC refurbishers, is to provide a complete Internet ready PC solution with unmatched functionality and price to its chosen markets.... The result is

---

[12] This point has been emphasized in various articles by Jhunjhunwala, available at http://www.tenet.res.in.

[13] See http://www.freeplay.net/newsite/company/freecom.html. See also the Computers for Africa Project which directs African users to reconditioned computer suppliers in the US. See http://www.computersforafrica.org.

that Green PC Inc. can offer unprecedented computing power, ease of use, and cost effectiveness with its Internet—ready sub—$ 300 line of computers.''[14]

Prolonging the life of existing computers can also be facilitated by the use of particular forms of software, which, in one way or another, avoid or ameliorate the problem of premature obsolescence referred to above. Consider, for example, the potential afforded by the use of open source (as distinct from proprietary) software such as Linux, as illustrated in the educational context by cases drawn from two developing countries. From the Philippines it is reported that ''a number of local schools are discovering that Linux can save them from inevitably increasing their tuition fees every time when they have to upgrade their computer systems.

Educators who discussed the advantages of Linux in schools …agreed that this free open-source operating system that can run on low-end machines can free them from the financial bounds of commercial software distribution and upgrades.''[15]

Similarly, according to an article written in 1999 (Murray) the Mexican government was then installing the Linux operating system in 140,000 computer laboratories at elementary and mid-level schools. The open-source software was chosen ''because it would have been too expensive for all the proprietary system software licenses'' and also because ''*Older and less expensive hardware can be used*'' (Murray, 1999, emphasis added).

To the possibilities thus afforded by open-source software, should be added the design of software that is specifically intended to lengthen the life spans of existing computers and to prevent them from being discarded prematurely (from the point of view, that is, of certain users in developing countries). In fact, precisely this idea has already been exploited by an American firm called ''New Deal Inc.'' which was ranked second in Fortune Magazine's list of ''13 cool companies for 2000''.[16] New Deal has developed software for personal computers ''with a design approach of 'sustainable software' that enables it to enhance functionality without regularly obsoleting hardware.''[17] In particular, this software is able to run effectively on any PC from the latest Pentium III to the earliest 286'' (see). Although its operating system costs only 70 US$, as opposed to the price of 180 $ for Windows 98 alone, New Deal does neither view itself as a direct competitor of Microsoft nor does it aspire to capture the market for large corporations that can afford regular upgrades of computer hardware and software. Its clientele, rather, ''includes small business, consumers who do not want to spend a fortune on a computer, and schoolchildren and communities in India, Africa and Latin American'' (Creswell, 2000). With regard to the last-mentioned category of potential users, it is worth noting that a recent educational program designed by the firm contains all the applications that are needed to teach basic computer literacy and Internet use and yet requires only a 286 processor, 640K RAM and 9 MB of hard disk space.

---

[14] The establishment of Green PC Inc., a subsidiary of New Deal Inc., was announced on November 1, 2000. See http://www.newdealinc.com under press releases.

[15] Computer World Philippines: Freeware OS attractive to schools, July 16, 1999 (available at http://linuxtoday.com).

[16] See http://www.newdealinc.com/main_page.asp?page_name=news

[17] See http://www.newdeal.inc.com.

Designing low-cost computers

As in the case of telecommunications technologies described earlier, numerous attempts to design low-cost computers have been made in the developing countries themselves. Probably the best known of these is the so-called "Simputer" which was jointly designed by the Indian Institute of Science and a private company based in Bangalore, with the explicit objective of bringing "the Internet to the masses in India and other developing countries".[18] Slated for a public launch not later than April 25th, 2001 at a price of around 200 US$; the "Simputer" will enable non-literate users to browse the Internet using pictures and its text-to-speech capability will permit the Web content to be delivered in local languages. Part of the reason why the product is so inexpensive relative to most other personal computers, is that all its electronic components are purchased in volume "off-the-shelf", while its software is mainly open source (such as Linux).

In another large developing country, Brazil, an indigenously designed low-cost computer will also become available in 2001 at a price similar to that of the Indian "Simputer" (namely, between 200 and 250 US$).[19] As part of a new government initiative to build, sell and finance low-cost computers in Brazil, the prototype was built by the Federal University of Minas Gerais and "includes simple software, a processor similar to a 500 MHz Pentium and 64 MB of memory …. For poorer Brazilians, the government savings bank will offer credit of up to 2 years and installments of around $ 10 a month" (see footnote 19). The Minister of Science and Technology expects the new computer to reach about 23 million people in that country.

Still another low-cost personal computer that is due to appear in 2001 as the result of research conducted in an industrializing country, is the "Information PC" from Via Technologies Inc. in Taiwan. This product is described as being "small and inexpensive, spanning price points from US$ 199 to 499, and is comprised of industry standard components that deliver the right balance between cost, functionality and performance".[20] The "Information PC" is said to be targeted at "budget-conscious consumers, schools, government organizations, and developing countries. The PC is optimized for mainstream Internet applications and services, such as e-mail and Web Surfing" (Hung, 2000).[21]

The development of such low-cost personal computers has not, however, been confined to developing or newly industrializing countries. For, there are apparently also large number of users in the developed economies who are attracted to the concept of a cheap alternative Internet appliance. In particular, for users requiring only e-mail and Internet access, the so-called "New Internet Computer" is already available from a corporate spinoff of the US software firm "Oracle" for only 199.99 $.[22] Without a hard disk drive and running on open source Linux

---

[18] See A Simputer aims at the developing world (available at http://www.pcworld.com. See also the discussion in *The Times of India*, August 8, 2000 (available at http://www.timesofindia.com) and the Simputer FAQ at http://www.simputer.org.

[19] Technology: cheap computers to help Brazil, get wired. *The Nando Times*, January 31, 2001 (available at http://www.nandotimes.com).

[20] The VIA information PC-bridging the gap (available at http://www.cyrix.com/Value-Internet/ipc_cost_performance.htm.

[21] Hung F. Via takes aim at low-cost PCs. *Electronic Buyers' News*, August 28, 2000 (available at http://www.proquest.umi.com).

[22] See http://www.oracle.com.

software, this device is equipped with a 56K bit/s modem and a Netscape browser, which are sufficient for access to the World Wide Web. The "New Internet Computer" is said to be targeting consumers, small business and schools. Since the initial launch of this product in August 2000, "Oracle" has brought out "version 2.0", which it describes as a free update that adds a number of important new features to the original version, including improved overall performance and reliability.

In concluding this section on low-cost computers for developing countries, what bears perhaps most emphasis is the dual role played by various forms of software in the examples we have cited. On the one hand, that is to say, we found that certain types of software were able to extend the lives of existing computers and thereby reduce their costs. On the other hand, open-source software such as Linux was seen to form an important part of computers designed specifically for users who are unable or unwilling to pay the price at which conventional versions of these products are sold.

Communication Technologies

The examples we have considered in the previous sections help, directly or indirectly to lower the cost of gaining access to the Internet. What we have not yet considered, however, are low-cost alternatives to the Internet itself. Although these alternative technologies are far from being perfect substitutes for full (TCP/IP) Internet connectivity, they nonetheless

> allow basic network services like e-mail and provide vast improvements over other, more traditional communications options such as fax, telex, and the postal system. These alternatives are based on 'dial-up' access over normal phone lines to computers that collect messages and, in turn, distribute them in a similar manner to other computers as necessary until they reach their final destinations. Networks that send messages 'hopping' from computer to computer are known as 'store-and-forward' systems, and include UUCP (Unix to Unix Copy Program) and the PC-based Fidonet. It is important to note that these are not 'low technology' systems; indeed, the software that instructs messages to be 'packed' together, compressed, and sent complete with error detection and correction, all features that contribute to the low cost of the systems is quite sophisticated.[23]

Fidonet, moreover, provides yet another reason for rejuvenating older, discarded personal computers from the developed countries that were mentioned earlier in connection with the new, more versatile software systems manufactured by the New Deal Inc. For "While Internet and other high-technology computer networks require powerful machines, even some old, outmoded personal computers can run FidoNet programs, providing a communications link that is as fast as a telex—at a fraction of the cost" (Young, 1993, p. 33). Here again, therefore, as in some of the previous examples cited in the previous section, there is scope for breaking the costly cycle of mutually determined (and for many users unnecessary) increases in the sophistication of computer hardware and software.

---

[23] Electronic networking for West African Universities. American Association for the Advancement of Science, Sub-Saharan Africa Project, 1993 (available at http://www.sas.upenn.edu).

Although some observers view these store-and-forward networks as outdated and likely to be phased out in the near future, others feel that "store-and-forward" will continue to play a crucial role for a long time to come, especially for those on the networking and geographical "edge".[24] As far as I am aware it is still the case, for example, that SchoolNet in South Africa relies on a multi-user UUCP service in order "to make effective e-mail available to all schools at the lowest possible cost".[25]

In any event, when the transition to the full Internet is made in developing countries, it may often take place in an institutional setting (such as a school, telecenter or office) where one frequently runs into the problem that there are more computers available than Internet connections (which implies that people have to wait in turn to go online). This problem can, of course, be surmounted in various ways, such as installing another telephone line or wiring the computers together, but in practice these solutions may be either unavailable or too expensive. Recently, however, two major US computer manufacturers have brought out a simple device, which for only a few 100 $, permits wireless communications between multiple computers and the Internet (within a certain limited radius). In a classroom, for instance, one could provide wireless communications to multiple computers near a "base-station" located in a nearby laboratory or hallway, using the devices in question (one of which, "Airport" is manufactured by Apple Computer Inc. and the other, the "Residential Gateway", is produced by Lucent Technologies).

Potentially, more far reaching for developing countries, however, may be the use of these devices as part of the emerging community wireless local area network (WLAN) movement. In essence, the idea is to take the indoor form of wireless networking described above "outdoors", by using among other things, rooftop radio antennas.[26]

> Call it "the free-network movement" …a bubbled-up-from-the-underground effort to spread high-bandwidth wireless connectivity everywhere. In their attempt to create a user-generated alternative to a top–down industry, in this case, telecom … [current community based wireless] initiatives …look a lot like the original *Napster*, the Web itself or the world of *free-software*. The free-software movement, in fact, is a working model for many wireless Ethernet pioneers. Many people involved …view it as free software's newfound twin: open-source development of operational antennas rather than operating systems.[27]

Some such people, accordingly view the community WLAN movement as a potentially powerful force in overcoming the digital divide within as well as between countries.[28]

Conclusions

It seems clear enough that most information technology innovations in the developed countries are designed for high, rather than low-income users (be they firms, households or schools). It seems equally clear that as a result thereof, these innovations are not widely affordable by

---

[24] Oh, when E-mail was new, *Wired*, June 19, 2000 (available at www.wired.com).

[25] See http://www.school.za.

[26] See http://wlan.org.uk and http://www.consume.net. These sites contain a wealth of information about this idea.

[27] Cave D. Unchaining the net. December 1, 2000 (available at http://www.salon.com). Numerous other articles on the same topic are available at http://www.consume.net.

[28] In the UK, for example, the movement has already gained considerable momentum. An initiative in Latvia may serve as a potential model for developing countries. The case is described at the site http://wlan.org.uk.

potential users in developing countries and that such innovations do not consequently in themselves usually help to bridge the massive digital divide between rich and poor countries. What is needed for this purpose, accordingly, is to provide the latter with lower cost versions of information technologies such as telecommunications, computers and electronic communications such as e-mail and the Internet (as has already occurred, for example, in the case of earlier communications technologies such as radios, which have been specifically designed for Third World conditions. In particular, battery-free radios that operate on an internal spring and solar power have, since their introduction in 1996, reached more than 3 million people in developing countries who lack access to electricity and battery power[29]).

The problem, however, is that information technology is highly fragmented and difficult to access (a problem that, ironically, the Internet itself has failed to resolve)[30]. The purpose of this paper, accordingly, has been to provide policy makers not only with a description of (and reference to) some of the most important forms of low-cost information technology that are already in use, but also with an indication of where such technology is likely to emerge in the near future. Thus by combining both existing and emerging innovations, we hope that the discussion will be in a form that maximizes the relevance to policy makers in developing countries who are concerned to lessen the digital divide that now so manifestly separates them from the developed countries.

References

Creswell, J. (2000). New deal. *Fortune Magazine*, 26 June 2000 (available at http://www.fortune.com).

Gupta, R. (2000). Inmarsat in village telephony. In S. Bhatnagar, & R. Schware (Eds.), *Information and communication technology in development: Cases from India* (pp. 141–148). New Delhi: Sage.

Hudson, H. (1997). *Global connections*. New York: van Nostrand Reinhold.

Hung, F. (2000) Via takes aim at low-cost PCs. *Electronic Buyers' News*, 28 August 2000 (available at http://www.proquest.umi.com).

James, J. (2001). Bridging the digital divide with low-cost information technologies. *Journal of Information Science*.

Jhunjhunwala, A. (2000). Personal communication, 28 December.

Jhunjhunwala, A., Ramamurthi, B., & Gonsalves, T. (nd). The role of technology in telecom expansion in India (available at http://www.tenet.res.in).

Murray, D. (1999). Linux in Mexican schools (available at http://livingstonmontana.com/access/dan/120linuxinmexicanschools.html).

O'Meara, M. (2000). Harnessing information technologies for the environment. In *State of the World 2000* (pp. 121–200). A Worldwatch Institute Report on Progress toward a Sustainable Society, New York: W.W. Norton.

Rodriguez, F., & Wilson, E. (2000). Are poor countries losing the information revolution? InfoDev working paper, The World Bank, Washington, DC.

Stata, R. (2000). Accelerating the internet revolution in developing nations. Paper presented at International Conference on Affordable Telecom and IT Solutions for Developing Countries, February 28–March 2, Indian Institute of Technology, Madras (available at http://www.tenet.res.in).

Vijayaditya, N. (2000). A wired village: The Warana experiment. In S. Bhatnagar, & R. Schware (Eds.), *Information and communication technology in development: Cases from India* (pp. 132–140). New Delhi: Sage.

Young, J. (1993). *Global network: Computers in a sustainable society*. Washington, DC: Worldwatch Institute.

---

[29] Radios are so crucial because some 80 per cent of those living in rural areas still depend on them for information. In these areas, moreover, not only is electricity often non-existent but batteries are also expensive and tend to be of low quality. See http://www. freeplayfoundation.org.

[30] Although in principle, of course, it would be possible to establish a site on the World Wide Web dedicated specifically to low-cost information technologies for developing countries.