Low-cost computing and related ways of overcoming the global digital divide

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1. Introduction

'The single pervasive theme of the twenty-first century', according to one observer, 'has already been decided. It is the "digital divide" and whether it can be bridged. Seldom has a potential social malaise engaged so many minds everywhere at the same time. It is as if concerned people around the world have simultaneously decided not only that the problem should be solved but that it actually can be.

'Everyone is getting in on the act, from the United Nations and the Group of Eight at the top, to university departments and community groups at the other end of the scale' [1].

The purpose of this paper is not to add yet another opinion to the debate on whether the digital divide between rich and poor countries can or cannot be bridged. The goal is rather to focus on the role that low-cost information technology can play in helping to bridge this gap. There will be no attempt, however, to encompass all forms of information technology, partly because one of them, telecommunications, has already been extensively debated from this point of view, under the headings, for example, of low earth orbiting satellites, wireless local loop technologies, mobile phones and undersea cables (e.g. Main [2], Kayani and Dymond [3], Hudson [4] and various publications from the International Telecommunications Union; James [5] has a brief discussion of some of the issues to be raised in this paper). What have received much less systematic attention, by contrast, are the various ways in which low-cost computers and other related devices can help to bridge the digital divide by enabling developing countries to gain greater access to the internet and the World Wide Web.

In seeking to describe these various mechanisms, and thereby fill an important gap in the literature, it will be necessary to combine information from two debates which, for the most part, have been artificially kept almost entirely separate from one another, namely, the *national* debate (conducted most intensively in the United States) on closing the digital divide within particular rich countries [6] and the *international* debate on the degree to which information technology has been differentially exploited across (rather than within) individual countries. For, as we shall see, some of the innovations that are designed to close the internal gap are equally (if not more) important vehicles for closing the international gap between rich and poor nations.

Let us first, however, examine the extent of the challenge that needs to be confronted, among other ways, by low-cost innovations in information technology in general and computing technology in particular. (Obviously there are many aspects to bridging the digital divide and it is not claimed that technology alone is capable of achieving this.)

2. The extent of the digital divide between rich and poor countries

A complete measure of the digital divide between rich and poor countries at any moment of time would

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require data on all aspects of the divide, such as mobile phones, fax machines, e-mail and internet access, telecommunications and so on [8]. For our purposes, however, what bears emphasis is not so much the extent of the divide in this broad sense, as a narrower concept that is defined in terms of the numbers of computers and internet hosts in countries with varying income levels. These more limited data are contained in Table 1, which shows, among other things, the enormity of the gap between the OECD countries on the one hand and the countries in South Asia and Sub-Saharan Africa on the other. The table also indicates that the ratio of internet hosts to computers is substantially higher in the OECD than any other region, thus implying that the digital divide between rich and poor in the former type of information technology is even more accentuated than the gap in the latter. Also, from the point of view of poor countries seeking to close the massive gap in internet access, it follows from these observations that low-cost innovations in computer hardware and software will be most effective if, in one way or another, they are also able to promote this more ultimate objective (as indeed is the case with several of the examples described below).

3. Classifying the sources of low-cost computing technology for developing countries

For the sake of expositional simplicity it is useful initially to distinguish between a number of separate sources of low-cost computing technology for developing countries. Subsequently, however, it will be argued that, in practice, many of these sources are related to, or combined with, one another. Indeed, to a considerable extent, the scope for low-cost computing (and related information technologies) *arises precisely out of complementarities between the various sources that this paper will now seek to describe*.

Table 1
Elements of the digital divide by region 1992–1997

Region	Personal computers	Internet hosts	GDP per capita
OECD	195.37	138.25	20,113.50
Middle East	32.16	5.31	8941.47
East Asia	46.10	6.26	6270.63
Latin America and Caribbean	20.33	5.69	5635.80
Eastern Europe and transition economies	28.21	6.99	4027.36
Sub-Saharan Africa	5.05	4.72	1971.51
South Asia	4.72	0.13	1764.33

Note: figures in the first two columns are per 10,000 persons.
Source: Rodriguez and Wilson [8].

4. Open source vs proprietary forms of computer software

Whatever the relative merits of open source as distinct from proprietary software may be (a recent comparison was made in *The Economist*, 12 May 2001), it is difficult to conceive of any widespread diffusion in poor countries of computers that run on the latter type of operating system (the best known of which is, of course, Microsoft Windows). The problem is simply that proprietary software is sold in a form that customers can use, but not change, and the price charged for this proprietary product is usually prohibitively high by the standards of most poor developing countries. Consider, for example, the facts that the Windows operating system costs around US$100 and the Windows Office Suite applications may cost as much as US$800 in Kenya. In a continent where the average annual per capita income is less than US$250, proprietary software, with its accompanying licensing difficulties, is a major drawback for would-be Windows users [9].

Examples such as these have led some observers to argue more generally of the entire region that 'Under the proprietary software model, Africa is just investing in unattainable dreams because we cannot afford to pay all this money that the continent is paying for proprietary software' [9]. To many of those who hold such views, the open-source software model, by contrast, 'is the only way for Africa to ever leapfrog its status as an underdeveloped continent' [9]. In support of this view, supporters of open-source software such as Linux can point to examples such as the 'Silicon Bazaar' in Kenya, which has tailored free software for use by small and medium-sized firms at a price of just US$6.50 [9].

In general, however, the use of Linux in Africa is constrained, among other factors, by a flourishing market for pirated Windows software. Paradoxical as it may seem, the ease of piracy is said to be 'stopping many people from actively considering Linux for cost reasons' [10]. Much will thus depend in the future on the stance that African governments adopt towards the piracy of proprietary software in general and Microsoft Windows in particular. Indeed, open-source advocates

believe that, when African governments start viewing a deeper usage of technology as a higher priority than it currently is, they will decide to ditch proprietary software in favour of open-source software.

According to Mike Jensen, the author of the Africa Connectivity Report, this is already happening in countries like Mauritius and Senegal, where the governments have shown leadership in the adoption of Linux. Indeed, Jensen cites the lack of this leadership by African governments as an obstacle to the adoption of Linux. 'The main barriers to further use will be leadership', Jensen said. 'Only when the people at the top tell those down below they should use Linux rather than pirate will word go out' [10].

There are certainly other parts of the Third World where those in political office have heavily promoted the shift from proprietary to open-source software in government operations and, where successful, these endeavours have resulted in cost savings that are nothing short of spectacular. Perhaps the best example from this point of view is Mexico City where, with the strong support of the mayor and the city's technical coordinator, the municipal government recently 'announced plans to switch city computers to the Linux operating system and to use the money it saves to fund social welfare programs' [11]. For the municipality, the savings involved are estimated to run into millions of dollars, thereby adding to the US$3 million that have reportedly already been saved by the government in Microsoft licences through a programme to install the Linux operating system in Mexican public schools (a figure which is expected to rise substantially by the time installation has occurred in all 140,000 schools in late 2003 [12]).

Another recent case from Latin America where political influence was successfully exerted on behalf of the Linux operating system occurred in Argentina and more specifically in Salta province, one of the poorest regions in that country. The influence in question was exerted by a professor at the Universidad Nacional de Salta, who also happened to be an active member of one of the political parties in the ruling Alliance. In his capacity as 'head of the Department of Environmental Policy in the regional capital of Ciudad de Salta [he] saw to it that all computers ended up running Linux' [13]. Yet, important as the installation of open-source software at the Universidad de Salta and the Department of Environmental Policy is as an example of what can be achieved in a poor remote area of a developing country, it is not the first and only application of its kind in Argentina. One also has to take into account the fact that the computers at the Secretaria de la Gobernacion, the Central Police Department and the Catholic University (the other significant educational institution in the province) already run Linux [13].

The open-source movement might, however, find its most extensive application in China, where it is now allegedly government policy to use the Linux operating system in all government ministries [14].

5. Proprietary software to promote low-cost internet access

In the previous section, Microsoft Windows was taken as the prototypical example of proprietary software that militates against low-cost computing in the Third World (and for that matter in developed countries as well). There is, however, no *intrinsic* technical reason why proprietary software should have this effect and in fact a US-based firm called New Deal Inc. has deliberately sought to create a software package that exerts precisely the opposite influence of promoting, rather than inhibiting, low-cost access to the internet in developing as well as developed countries.

The manner in which this is accomplished is perhaps best understood in relation to the way that the major forms of proprietary software currently contribute to the premature obsolescence of computer hardware, especially in the United States. According to one article published in 2000, for example, 'Over the last three years 62 million computers were "rendered obsolete" in terms of their ability to run standard software [in the US]' [15]. The cause of what the author refers to as an 'epidemic of functionally obsolete computers' is thought to lie 'not in the machines themselves, which were all built with an average functional lifespan of at least eleven years, *but with the software industry. Newer faster software continuously demands newer faster computers*' [15]. These incessant demands, in turn, by continuously driving up the price of hardware, help to explain how a digital divide in the United States can co-exist with a situation where millions of relatively new computers are being discarded each year in that same country (recent data show, for example, that ownership of computers by households in the lowest income bracket of below US$15,000 per annum was only 19% as against a figure of 86% among households with an income level of more than US$75,000) [6].

If, however, the mutually interactive (upward) spiral described in the previous paragraph was able to be reversed by computer software which rendered older vintages of hardware more, rather than less, effective, one would expect, following precisely the same logic,

a narrowing rather than a widening of the digital divide. What is remarkable about the software package designed by New Deal Inc. is not only that it tends to move the entire causal chain in this alternative direction, but also the age of the hardware to which it can be applied (and hence the degree to which the digital divide can potentially be overcome). New Deal Office 2000, for example, provides the user with a wide range of programs including a web browser and e-mail for as little as US$70 and the hardware requirements are a mere 12 MB of hard disk space on a 286-compatible processor with 640K of RAM (and it can also be run very cheaply on a local area network; see www.newdealinc.com).

From the point of view of low-income users in developing countries, the potential of this innovative software program is not confined, however, only to the marked extent to which it reduces the hardware constraint to internet access (about which more below). It is also the case that the program is designed explicitly to simplify use of the older hardware vintages thus hopefully acquired. In particular, 'New Deal is computing made simple; the best features of this suite as far as beginners are concerned are the manual and the selectable skill levels. This is a guide really and truly meant for the newest of new users. It explains how to use a mouse, how to drag-and-drop, what windows, applications and menus are, and a user can choose one of four skill levels based on their computer experience. Each level allows access to a different set of options so that beginners can familiarize themselves with program basics first, gradually moving up to more complex functionality at their own pace. For instance, Level 1 in the word processing program gives access only to a simple font formatting and text alignment buttons, which makes for an infinitely more comprehensible experience than being confronted by 59 different buttons as presented in Microsoft Word's standard interface' [15].

This source has been quoted so extensively because the cost of information technology as noted above is only one aspect (albeit an important one) of closing the digital divide between rich and poor countries. Of no less importance are the various user capabilities associated with this type of technology in general and computers in particular, because, if we have learnt anything from the transfer of technology to developing countries over the past few decades, it is that capability building is a difficult, lengthy and often expensive process (on the role of technological capabilities in industrialization see Lall [7]). And while it is not intended to engage here in a discussion of the many policy issues that are involved in this process, it is intended to emphasize the role that software inevitably plays in it.

6. The need for refurbished computers in developing countries

So far, the argument has been advanced in favour of open source and proprietary software of a particular kind in order to promote low-cost computing in developing countries. Since both these forms of software can be run on older hardware (Linux, in fact, was originally created for the 386 Intel processor), mechanisms need to be in place for the transfer of such products to users in the developing countries themselves. These transfers, in turn, can be effected commercially or non-commercially involving, for example, non-governmental organizations (NGOs) and aid donors.

Most prominent in the former category is probably New Deal Inc., the same firm which designed the pro-poor software program described in the previous section. New Deal has in fact itself pursued that innovation to its logical conclusion by combining it in a single package with low-cost refurbished computers. In this way, the company aims to bridge the so-called digital divide by offering easy-to-use and inexpensive PC software, PCs and internet service worldwide. At present it is premature to predict the extent to which this goal will actually be achieved (the hardware component of New Deal's operations, after all, was only announced on 1 November 2000). Nevertheless, it is difficult not to be impressed by the potential afforded by this product for closing the digital divide when one considers that, 'For a flat $100 . . . New Deal offers a complete 486 or early Pentium-class PC, refurbished, plus a full set of applications, word processing, database, spreadsheet, solitaire and e-mail and web service' [16].

Freecom is another commercial venture dedicated to taking the discarded computers of the rich and making them available at affordable prices to the poor. According to one recent source, this firm is already 'fixing up about 300 units a day [and] its initial goal is 40,000 a year donated by upgrading SA [South Africa] corporations and from the US via Per Scholas, a nonprofit computer recycler headquartered in New York's Bronx borough. Per Scholas has close ties to Wall Street firms like Chase and JP Morgan, whose demand for the latest machines is immense and which face mounting costs retiring used equipment. PCs are full of heavy metals – and many US jurisdictions will no longer allow them simply to be tossed into landfills – so, for a fee, Per Scholas takes them, converting some into scrap, refurbishing the rest

for schools and the like, or sending them to Freecom, which takes 486s and low-end Pentiums and turns them back into marketable products' [17].

The transfer of used computers from developed to developing countries can also be accomplished by not-for-profit institutions, such as Computer Aid International in the UK, which relies on volunteers based in that country to recycle donated computers for re-use in developing countries (especially in schools and community organizations). Over the past three years or so, Computer Aid International has managed to send 6000 fully refurbished computers to needy organizations in developing countries, ranging from trade unions in Namibia to the visually impaired in the Caribbean [18].

The World Computer Exchange is also an NGO that concerns itself with recycling used computers from developed to developing countries. More specifically, the exchange obtains working computers from firms in the USA and supplies them to educational institutions in Africa, Asia and Latin America. These activities are funded in part by international institutions such as the UNDP, which through its Sustainable Development Networking Programme has agreed, for example, to finance the shipping costs of certain projects in Bangladesh, Benin, Cameroon and Vietnam. The World Computer Exchange is currently said to be working with 42 partner institutions and 80 potential partners in 42 countries, which collectively have signed on more than 700 schools as suitable recipients (information about the Exchange can be found at www.worldcomputerexchange.org, as well as in *Balancing Act*, 22 January 2001).

The so-called 'digital partnership' represents yet another attempt by an NGO to exploit the possibilities afforded by the rapid 'obsolescence' of computers in the corporate sector of developed countries in general and the USA in particular. Briefly stated, its mission is to 'mobilise the immense problem solving capability of people in business and the vast information, technology resources they dispose of each year . . . to do something immediate and practical about lack of skills and internet access which create a digital divide . . . It involves linking systems and organisations that do not naturally collaborate . . . to contribute through a new partnership across sectors and countries to achieve scale and impact' [19].

The Digital Partnership plans to launch a number of pilot projects in developing countries, one of which will take place in South Africa, with financial assistance from the World Bank. According to the British NGO that is coordinating the Digital Partnership (the Prince of Wales International Business Leaders Forum), this project aims to place between 60 and 100,000 computers in 5000 South African schools and community centres (personal communication from the Prince of Wales International Business Leaders Forum, 29 June 2001).

In this and the other projects mentioned above in connection with computer recycling, the very nature of the process requires the forging of relationships between institutions that would otherwise have little or nothing to do with one another (as is perhaps most obviously the case with large corporate entities in the developed countries and remote rural schools in the Third World). However, this crucial 'bridge-building' function is made all the more complex by the fact that the co-ordinating institutions usually aim to do far more than simply transfer low-cost hardware to needy groups in poor countries. Their goal, rather, is to also provide the skills and other resources that are required for the effective use over time of the computers thus donated. In one case, for example, an attempt is being made to forge links between schools in different countries so as to help build user skills and capabilities in the recipient institutions. In another case, involving the Digital Partnership, co-operation will be sought at the country level from institutions as diverse as customs authorities, relevant public education and training institutions, agencies such as the World Bank and UNDP, non-profit partners and business supporters. This will be coupled to special capacity-building programmes to develop 'breakthrough performance amongst community partners' [19].

7. The redesign of hardware to lower the cost of internet access

So far, various forms of software have been considered, with and without the use of refurbished computers from developed countries, as sources of low-cost computing for developing countries. In addition, *new* forms of hardware will now be considered that are designed specifically to lower the cost of internet access for users who would otherwise be excluded from the myriad benefits of connectivity.

In this category fall, first of all, various computers that are already (or soon will be) available for as little as US$200–300. Interestingly, a number of such products have originated in and for the developing countries themselves (especially the relatively industrialized parts of the Third World, such as India, Brazil and Taiwan). In order to bring about so drastic a reduction in costs, the designers of these remarkable innovations have employed a variety of different tactics. The

so-called Indian 'Simputer', for example, which is expected to become available at a price of around US$200 in 2001, is so inexpensive in relation to the standard personal computer partly because all its electronic components are bought in volume 'off the shelf', partly because its software is mainly open source, and partly 'because it has also extended the free software concept to the hardware design of the . . . platform' [20]. In Brazil, a low-cost 'volkscomputer' commissioned by the government will be sold to low-income earners on installments (for around US$15 per month) and installed in public schools (where the latter endeavour alone is expected to bring internet access to some 7 million children) [21]. Apart from the inclusion of simple software, this indigenously designed computer is able to achieve cost reductions because it contains neither a hard drive nor the ability to use floppy disks. What it does include is a modem, a colour monitor, speakers, a mouse and a simple internet-browsing facility. The result, according to the designer of the product, is a personal computer 'stripped of its fat'. Much the same can also be said of the 'New Internet Computer' which was developed in the USA for users requiring only e-mail and internet access and is already available for only US$200. Lacking a hard disk drive and running on open-source Linux software, this device is said to be targeting consumers, small business and schools (for details see www.thinknic.com).

In the second category of new forms of hardware designed to lower the cost of internet access in both developed and developing countries is a product offered by Worldgate Communications Inc., 'which obviates the need for a separate computer or modem. Instead, Worldgate offers internet access via a cable set top box using a common household television and a special keyboard' [22]. Among developing countries, India would seem to be especially well-suited to this technology, in part because of the phenomenal growth that has occurred there in the number of cable television connections – from being practically non-existent in 1992, the number of connections grew to almost 40 million in 2000. (The spectacular growth of cable television in India is discussed by Ashok Jhunjhunwala, 'Unleashing telecom and internet in India', available at www.tenet.res.in. He regards the most important lesson to be drawn from this experience as being one of affordability. In particular, the cost of a cable connection, between US$1.50 and 4 per month, is thought to be affordable to almost 60% of all Indian households.) Since there are currently only some 1 million internet connections in that country, one is tempted to ask whether the availability of cable television access could not drive up this figure in an equally spectacular fashion.

Certainly the partnership formed by Worldgate itself with Asianet Satellite Systems in 2000 already provides some grounds for optimism. The idea is that 'Asianet will deploy the WorldgateSM Service through Motorola's SURFviewTM platform, a $99 set-top box. By breaking the $100 barrier for an advanced interactive set-top box, SURFview enables cable operators worldwide to provide internet access at a very low monthly fee. The Worldgate Service can also convert the user interface to the language and culture required for an international marketplace. According to India's National Association of Software and Service Companies (NASSCOM), approximately 75 million people in India have television sets compared to 4.3 million with PCs and 26 million with telephones. In a country with a population of more than 1 billion people, this represents a huge potential for non-PC based Internet access.

'. . . Worldgate combines the cable infrastructure with the television platform so subscribers are able to reach the internet without a personal computer or any additional phone lines. Worldgate does not require an in-home computer, phone lines, costly set-top appliances, special training or high monthly service charge. All that television viewers need to receive the Internet . . . is a set-top box and a remote control or a wireless keyboard, all of which are supplied by the cable operator. (Note too that access to the internet via the television is suitable for users with and without computer experience.)' [23].

China is another large developing country where the ownership of televisions far outstrips the rate of computer adoption and where, to this extent, the potential for growth in the diffusion of set-top boxes would seem to be substantial. Indeed, by 1999 this commercial potential had begun to be exploited by Beijing Telecom and further initiatives have quickly followed, leading at least one observer to predict that 'Because of their low cost compared to a personal computer, set top boxes . . . could become the dominant means of internet access [in China] in a few years' [24] (see also [25], which also forecasts a rapid growth of set-top boxes in China, where television ownership far outstrips the adoption of personal computers).

8. Low-cost internet access via community wireless local area networks

The previous sections examined various means of gaining low-cost access to the internet via separate,

'stand-alone' computers, as opposed to machines that are networked to one another in some particular way. Yet, it is precisely such connections among numerous computer users that may offer the most promising future model for developing countries seeking to gain low-cost access to the internet. The essential idea here is to take a wireless technology developed to connect computers indoors and to apply it instead to forming outdoor connections (albeit, of course, with certain technological and institutional modifications).

The initial 'indoor' technology turns on a simple device, which, within a radius of some 50 metres, allows wireless access to the internet via so-called WLANs (wireless local area networks). The first such device, called AirPort (see www.freebase.sourceforge.net), was manufactured by Apply Computer Inc. and was followed subsequently by competing products such as the Residential Gateway (see www.wavelan.com) from Lucent Technologies, costing in each case no more than a few hundred dollars.

'Wireless networking, even over such short ranges, is attractive for several reasons. Because a single base station can support several machines, all the machines in a house or small office can be connected without having to run cables everywhere, and they can be moved around easily. *It did not take long for inventive individuals to begin using the technology, developed for indoor use, outside*' [26].

In one of its 'outdoor' versions, WLAN technology has evolved into a so-called 'free-network' movement, whose members supply free wireless internet access in their particular neighbourhoods, with the aid of a rooftop, an aerial and a 'router', which comprises an old personal computer, a standard network card and a wireless Ethernet card. (Probably the most comprehensive and up-to-date site on this movement is available at www.wlan.org.uk, which contains a useful list of operational WLAN sites located, however, almost entirely in the developed countries.)

'For instance, in parts of San Francisco's Presidio, a former military base turned vast park, you can sit on a bench and surf wirelessly – thanks to . . . a high-tech entrepreneur and founder of . . . an experimental internet service provider. He and his friends have put up antennae on several buildings nearby' [26].

Described thus, the community WLAN approach has an obvious affinity with the open-source software movement described above (in that both movements seek to lessen the hold of powerful commercial interests over the structure of the industries in question). Indeed, 'in their attempt to create a user-generated alternative to a top-down industry . . . in this case, telecom . . . [currently 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].

9. Conclusions

This paper has focused on the various ways in which low-cost computers and related devices can help to bridge the digital divide between rich and poor countries, by enabling the latter to gain a greater degree of access to the World Wide Web than would otherwise be possible. To this end, a number of different sources of low-cost computing technology have been classified, which, for the sake of expositional clarity were kept largely separate from one another. It soon became apparent, however, that in practice these different sources tend to complement one another and indeed that the scope for low-cost internet access is often defined precisely by such interactions.

For example, numerous cases have been seen where software innovations impinged on the type (and hence the cost) of computer hardware that was required for access to the internet. Conversely, it has also been noted that the cost of hardware designed for low-income users varies according to whether one type of software rather than another is employed. In yet another example, it has been seen how the philosophy behind one particular movement to make computing more widely accessible has influenced innovations in other areas of the industry where low-cost access to the internet is also at stake. Such complementarities as these are important, because low-income populations in developing countries need to take advantage of as many (and as generous) cost reductions as possible (such as combinations of open-source software, donated computers and free networking) if they are to make any discernible progress towards overcoming the digital divide that currently separates them from the developed countries.

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