Chapter 3

The Technologies: Identifying Appropriate Solutions for ‘Development’ Needs

Tim Unwin

- The convergence of technologies enabled by the shift from analogue to digital systems is transforming the ways in which we conceptualise ICTs; the challenge is to identify ways of using this new potential for the benefits of poor and marginalised communities
- There are many alternative hardware and software solutions available; the choice of the optimal solution for a particular ‘development’ issue depends on a wide diversity of economic, social, political and ideological factors.
- ICT4D initiatives need to be driven by the provision of appropriate technological solutions for the problems faced by poor and marginalised people and communities, rather than purely by an interest in these physical technologies themselves
- Those implementing technological solutions need to ensure that they are context specific and adapted to local needs and conditions

Chapters 1 and 2 have explored some of the most important reasons why information and communication are central to ‘development’ processes. This chapter now turns to an examination of the physical technologies that can be used to support these information and communication needs. Two key related issues must be emphasised right at the beginning of the chapter. First, it is essential to recognise that the physical technologies by themselves have little development impact. It is only when they are used effectively to deliver on the aspirations of poor people and marginalised communities that they may be able positively to influence people's lives and livelihoods. Indeed, ICTs are often a financial drain on communities until there is sufficient wealth generated for them to provide enough profit for their continued use. Second, ICT4D initiatives are not sustainable or effective unless the technologies embedded within them deliver on the demands of users in appropriate ways. There is little point simply in introducing the physical technologies, if users cannot see any economic, social or political benefit in paying for them. For this to happen, it is essential that potential users have a sound understanding of how they can use new Information and Communication Technologies (ICTs) beneficially. People at all levels, from government officials to merchants, farmers and street children, need to have a vision of how these technologies can be used to enhance their lives if they are to grasp the rich potential that such technologies have to offer. One of the most important challenges facing those implementing ICT4D initiatives is therefore to identify how best to respond to the needs of poor and marginalised communities once they have recognised this potential, and then to help them to develop innovative solutions that will enable them to achieve their aspirations.

The central purpose of this chapter is to provide a broad introduction to some of the diverse physical technologies that are referred to by those working in the field of ICT4D. It adopts a broad conceptualisation of these technologies, with the first section suggesting that we need to be flexible in our definitions and approaches if we are truly to create effective technological solutions for the problems faced by the poor. The chapter then builds around a fourfold conceptualisation of ICTs, focusing on the technologies used in the *production*, *storage* and *sharing* of information and knowledge, as well as the *infrastructures* used to support them. Underlying the practical usage of these physical technologies, it is crucial to recognise that there are also important regulatory issues that determine the social, economic and political context within which they are introduced. The chapter ends by emphasising the importance of the debate between those advocating 'proprietary' and 'open' technological solutions for development agendas. Throughout, the aim is to emphasise both the potential and the challenges associated with the use of specific technologies, so that those charged with implementing ICT4D programmes can have a realistic understanding of the contributions that each can make.

3.1 Information and Communication Technologies: a conceptual framework

There have been many approaches to the definition and classification of the technologies associated with information and communication. Frequently, the term 'ICTs' is used primarily to refer to the use of computers and the internet. The Wikipedia Information Technology Portal thus refers to IT (or ICT) as the subject that deals with 'electronic computers and computer software to convert, store, protect, process, transmit and retrieve information', and concentrates particularly on these different processes (http://en.wikipedia.org/wiki/Portal:Information_technology, accessed 3 November 2006). In contrast, the on-line TechTarget definition places emphasis on the different types of technology themselves, claiming that ICT 'is an umbrella term that includes any communication device or application, encompassing: radio, television, cellular phones, computer and network hardware and software, satellite systems and so on, as well as the various services and applications associated with them, such as videoconferencing and distance learning' (http://searchsmb.techtarget.com/sDefinition/0,290660,sid44_gci928405,00.html, accessed 3 November 2006). Weigel and Waldburger (2004, p.19) similarly use the term to refer 'to technologies designed to access, process and transmit information. ICT encompass a full range of technologies – from traditional, widely used devices such as radios, telephones or TV, to more sophisticated tools like computers or the Internet' (see also Von Braun and Torero, 2006). In trying to cut through this complexity, Hamelink (1997) has usefully sought to distinguish between capturing technologies (such as cameras and digital video recorders), storage technologies (such as CD-ROMs and film), processing technologies (such as application software), communication technologies (such as Local Area Networks) and display technologies (such as computer monitors or the screens of mobile 'phones).

However, in an increasingly digital world, these distinctions have become ever more blurred.

3.1.1 A digital world

In the past it was possible to distinguish between separate ICTs such as telephones and radios, but the fundamental change that has taken place since the late 1990s has been the widespread introduction of technologies that have enabled text, image and sound to be broken down into binary formats that have then allowed them all to be accessed through a range of new electronic devices. Not so long ago, for example, all cameras used films that had to be chemically processed before the images could be seen. Now, digital processing has fundamentally transformed the practice of photography, enabling users to access their photographs immediately and 'post' them on the internet through sites such as http://www.flickr.com (accessed 16 October 2007; see also social networking sites such as http://www.bebo.com or http://www.facebook.com) so that anyone in the world can see and access them almost instantaneously. This introduction of digital technologies has had two fundamentally important effects: first it has enabled single devices, such as the new generation of portable media players and 'phones to receive and display text, image and sound together; and second, it has permitted these multi-functional devices to become very much smaller and more mobile. The combination of miniaturisation with better use of power, enhanced compression of data, and digitalisation has led to a transformation in the potential of ICTs.

Traditionally, communication systems, such as telephones, radio and TV, functioned through the use of analogue technologies. The term 'analogue' is used here to refer to an analogy between cause and effect; as sound increases, for example, so too might the voltage of an analogous electrical system. Importantly, an analogue signal is one that continuously varies in both time and amplitude, and therefore all changes in the signal are meaningful. Using analogue systems, communication is enabled because small fluctuations in a signal can be conveyed by changes in the properties of the medium being used to transmit it. Transducers are used to convert energy of one type into energy of another that can then be transmitted. Thus, with the analogue recording of sound, a microphone is used to pick up variations in pressure caused by the sound, and these are then converted into changes in the current passing through it, or the voltage across it. The main problem with analogue systems, though, is that they are subject to random variations and disturbance known as noise. This is particularly the case, for example, when multiple copies of a recording are made, since the noise leads to a reduction in the quality of the signal. Likewise, radio or TV signals can pick up interference from other such sources, and this noise then leads to a diminution in the quality of the sound.

In contrast, digital systems quantise signals into discrete blocks, and any slight variations are treated as the values nearest to them, thus minimising the effects of noise and distortion. Historically, there have been numerous systems of digital communication, perhaps best seen with the use of beacons that could convey messages over long distances by line-of-sight connections simply by being lit or unlit. Likewise, Morse code and Braille are both forms of digital communication, the former using dots, dashes and different lengths of gaps between letters, the latter using a six-bit code in the form of raised dot patterns. However, the term is now most frequently used to refer to digital electronic systems, in which information is encoded into binary digital format through the use of complex systems of switches. The underlying principle, though, remains the same, in that information is converted into a presence/absence format, and can be stored and accessed through a diversity of media.

Although digital electronic systems have increasingly come to dominate the market since their widespread introduction in the music industry in the 1980s, it remains important to recognise that both digital and analogue systems have their own particular strengths and weaknesses (Beards, 1996; Crecraft and Gergely, 2002). Their key differences are in the ways in which information is encoded, processed and represented (see Table 3.1). However, the easier design and smaller size of digital electronic circuits has made them much cheaper to produce, and this is the main reason that they came to dominate the mass market in ICTs in the late 1990s.

[TABLE 3.1 HERE]

3.1.2 Capture, storage and information sharing: the importance of infrastructure and regulation

In conceptualising ICTs in this rapidly changing, and ever more dominantly digital world, it is helpful to think about these technologies as being associated with three main sets of processes: the capture of information, its storage, and the ways in which people access and share it. Underlying all these, there has to be a physical infrastructure in place that enables them to operate and be connected, and a regulatory mechanism to ensure that there are common standards in place for communication to be possible between devices (Figure 3.1). The ITU, for example, notes that as of March 2005 there were 'around 3,100 recommendations in force globally on topics from service definition to network architecture and security, from dial-up modems to Gbit/s optical transmission systems to next-generation networks and IP related issues' (http://www.itu.int/ITU-T/publications/recs.html, accessed 7 January 2008). This chapter focuses primarily on the physical technologies and infrastructure, while the next includes a discussion of regulation in the context of policy formulation and the implementation of IC4D partnership initiatives. One of the core features of our increasingly digital world, though, is that all of these structures are nevertheless blurring, and we are therefore functioning today in a much more fluid world than was the case only a decade ago. This opens up many new opportunities and challenges, and much of the potential for ICT4D in the future lies in the way in which these connections can be reconfigured for the benefit of the poor.

[FIGURE 3.1 HERE]

Means of information capture were traditionally discrete and generally quite big in size. Large typewriters and bulky cameras have now, for example, been replaced with ever more powerful slim-line digital cameras and keyboards. The complexity of recording music and voices onto the analogue sound medium of gramophone records has likewise been dramatically transformed into the contemporary process of digital recording through which people can readily capture their own voices and music using small electronic devices. The size of devices for storage has likewise been transformed, largely through the introduction of digital circuits. Moore's Law, propounded by Gordon Moore one of the co-founders of Intel as long ago as 1965, thus asserted that the number of transistors per unit area on an integrated circuit was at that time doubling every two years. Today, the law has been reinterpreted to assert that data density is now doubling approximately every 18 months. The technological advances that have underlain this mean that the size of storage devices has been reduced dramatically, while it has also been possible to increase their capacity at the same time. As Intel's web-site asserts, 'Moore's Law also means decreasing costs. As silicon-based components and platform ingredients gain in performance, they become exponentially cheaper to produce, and therefore more plentiful, more powerful, and more seamlessly integrated into our daily lives' (http://www.intel.com/technology/mooreslaw/index.htm, accessed 14th November 2006). In 1971, Intel's first processor, the 4004, had 2300 transistors in it; in 2006, Intel's Core 2 Duo Processors had more than 291 million transistors. The 4004's circuit line width was 10 microns, whereas the latest generation microprocessors have widths of .065 microns, fifteen hundred times smaller than the diameter of human hair (http://www.intel.com/museum/archives/4004facts.htm, accessed 14 November 2006).

Figure 3.1 is only schematic, but it does emphasise the great diversity of options that people can use to communicate and to manage information. This chapter does not explore all of these technologies, but it does aim to give a balanced overview of some of the most important of them, focusing particularly on the ways in which poor and marginalised communities can use them to gain information and to communicate more effectively. It begins by examining the increasingly sophisticated ways in which information is captured and stored, concentrating on three particular issues: the implications of changes in the use of printed material for libraries; the important role of film, video and audio material; and the dramatically increasing role of the internet. None of these technologies would be of any use unless there was appropriate physical infrastructure available to enable them to function effectively. The third main section of this chapter therefore focuses explicitly on four key aspects of infrastructure provision: the importance of cables and wires; the role of satellites; the increasing prominence of wireless networks; and then the need for appropriate energy solutions. This is followed by a section which explores the various benefits and challenges associated with the use of specific user interfaces, both for accessing information, and also for communicating more generally, concentrating especially on telephones, computers, new hand-held devices, and the role of radio, television and film. In addressing these particular technologies, however, it must emphasised once again that they are already all closely inter-connected and the boundaries between them will become ever more blurred in the future. In particular, the distinction between users and suppliers of information is one that is rapidly changing. The internet has thus enabled a much more fluid world of communication in which people can share information with each other, instead of having to rely primarily on the ‘supply’ of information by privileged organisations such as broadcasters and publishers, be they public service organisations or private companies.

3.1.3 Individual and communal technologies

All of the technologies noted above require both physical hardware and also programmes, or software, to enable them to be used effectively. Chapter 1 drew specific attention to the significance of IPR issues in the evolving world of ICT4D, and it is important here to address these issues in more depth. The final section of this chapter is therefore devoted to a review of the relative benefits and disadvantages of proprietary and open or communal software solutions in the context of ICT4D. In so doing, it seeks to resolve some of the more extreme positions held on these matters, by arguing that the key decision facing those wishing to implement ICT4D programmes is to identify the optimal solution for their particular context.

However, as an introduction, it is helpful to note some of the implications of different types of technology for the ways in which they may be of value in ICT4D initiatives. Figure 3.2, which draws in part on Wiegel and Waldburger (2004), thus illustrates that we can conceive of these physical technologies in terms of their costs to end users, their ease of access, and the extent to which they are communal or individual in emphasis. In general, we can envisage the two extremes of low cost, easy to use and communal solutions such as radio on the one hand, and high cost, complex and individual solutions such as personal computers linked to the internet on the other. While these categories are by no means mutually exclusive, it is generally the case that easier to use technologies are indeed cheaper, and have wider communal use than expensive and complex technologies. This is typified, for example, by the success of Grameenphone's Village Phone Program (http://www.grameenphone.com, accessed 28 November 2006) started in 1997 in Bangladesh, which was designed to provide universal access to telecommunication services in remote rural areas through a network of some 200,000 village phone operators, most of whom are women (for communal aspects of mobile 'phones, see also Geser, 2004; and Souter *et al*, 2005). While expanding the market for high cost, individualised technological solutions may well contribute to the economic growth that is seen by many as being central to development processes, alternative communal solutions may actually prove to be much more sustainable and relevant to the needs of poorer communities.

[FIGURE 3.2 HERE]

3.2 The Capture and Storage of Information

The introduction of small and relatively cheap information capture and storage devices has transformed the world in which we live. Not only is this a remarkable technical transformation, but equally importantly it offers a rare opportunity to change the traditional balances of power associated with the provision of access to information. In essence, new ICTs have provided a very significant chance for an increase in the democratisation of knowledge in ways that have not yet fully been grasped. This section of the chapter explores these issues in three main arenas: libraries, audio visual technologies, and the internet.

3.2.1 The changing place of libraries

Historically, library buildings have been the main place where information has been stored and made available for people to read. Indeed, as Klugkist (2001, p.197) has commented, 'until the 1980s and 90s, libraries virtually had a monopoly on the provision of information to students, teachers and researchers'. To be sure, more wealthy individuals often maintained their own collections of books, and official records were kept in national archives, but it was to libraries that most people went to find out about things if they had no other means of doing so. Moreover, libraries served a public good, in that they were usually free to use, and they frequently offered a range of additional services including the provision of general information about the local community as well as learning opportunities. Libraries, in essence, served the needs of those individuals unable to afford to purchase their own books and information.

During the last twenty years of the 20th century, two fundamental changes took place that mean that the libraries of the 21st century are now fundamentally different places from those that existed in previous centuries: first, the dramatic increase in the number of books, journals and other printed media being published has meant that it is impossible physically for most libraries to store this information; and second, the availability of digital technologies has enabled much of this information to be accessed in entirely new ways. The provision, for example, of both hard copy and digital versions of publications has completely transformed the world of publishing and academic research. While there are undoubted cost savings and environmental benefits in the shift from hard copy books and journals to digital publication, there nevertheless still remain problems in accessing such information in a sufficiently flexible and user-friendly manner. Thus, although digital book downloads are readily available for PDAs, most people still prefer to read 'real' rather than 'virtual' books. This is particularly the case with elderly people, whose eyesight might be failing. Likewise, many people still choose to print off copies of digital journal articles, rather than reading them on their computer screens because they find it easier to read them in this way.

In exploring what libraries will be like in the future, Klugkist (2001, p.197) has usefully suggested that they will have four main characteristics. They will be

> '(1) a gateway to information, whatever format this information comes in and wherever it is located; (2) an expertise centre; (3) a physical entity, not only in the sense of being a social meeting place and place of scholarly interaction, but also as a place where students and other users are provided with modern study facilities and adequate user support; (4) a collection centre of printed material'.

According to such arguments (see also Saunders, 1999), digital information will not therefore replace libraries as places where information is accessed, but rather the means of accessing this information within libraries will change. As Dendrinos (2005, unpaginated) has commented, 'The library as a building has been transformed to the library as an environment of electronic services established on a computer server or a network of cooperating servers'.

The emergence of digital libraries has required the development of completely new systems of cataloguing and searching publications so that information about them can readily be searched and made accessible to potential users (Lesk, 2005). In 1994, the USA thus established a Digital Libraries Initiative (http://www.dli2.nsf.gov/dlione/, accessed 22 December 2006), funded by the National Science Foundation, with a remit to 'collect, store, and organize information in digital forms, and make it available for searching, retrieval, and processing via communication networks - all in user-friendly ways'. Likewise, in the latter part of the 1990s, the New Zealand Digital Library Project began at the University of Waikato, and with the collaboration of UNESCO and the Human Info NGO from 2000, this led to the production of the Greenstone multilingual suite of Open Source software for building and distributing digital library collections either on the internet or CD-ROM (http://www.greenstone.org, accessed 22 December 2006; see also Bainbridge *et* *al*., no date, and http://www.nzdl.org, accessed 22 December 2006). This has provided a valuable tool for development related work, enabling the creation of digital libraries such as the Bibliothèque pour le développement durable library in 1999 (http://nzdl.sadl.uleth.ca/cgi-bin/library?a=p&p=about&c=tulane, accessed 22 December 2006) as well as the UNAIDS library (http://nzdl.sadl.uleth.ca/cgi-bin/library?a=p&p=about&c=unaids, accessed 22 December 2006). Other similar initiatives include the EU's Digital Libraries Initiative and eContent*plus* Programme (http://ec.europa.eu/information_society/activities/digital_libraries/index_en.htm, http://ec.europa.eu/information_society/activities/econtentplus/index_en.htm accessed 7 January 2008). Moreover, Google Book Search now provides a facility whereby users can read and search an array of books online, and the Google Books Library Project enables people to gain information about books not yet available online (http://books.google.com/googlebooks/library.html accessed 7 January 2008).

[INSERT CASE STUDY]

Accessing many of these new bibliographic resources nevertheless remains a challenge for the poor. Whilst university libraries in the world's rich countries subscribe to vast collections of on-line journals, the costs of such access remain prohibitively high for institutions in many of the poorer countries of the world. Likewise, having sufficient bandwidth as well as appropriate terminals from which to access these materials also gives rise to serious challenges, particularly for marginalised communities.

3.2.2 Film, video and audio materials

As Chapter 2 highlighted, the use of film and audio in development practice has a long tradition. However, recent advances in digital technologies have completely transformed the production and storage opportunities associated with such media. Whereas in the past, it was complex, costly and bulky to make films or audio-tapes, the use of small digital recorders has brought this opportunity to many people in a relatively easy to use, and low cost context. Moreover, the explosion of interest in sharing still and video images among friends and communities through the internet, using sites such as http://www.flickr.com, http://www.youtube.com or http://www.myspace.com (accessed 22 December 2006), reflects the scale of the social demand for such practices. YouTube, which was only launched in February 2005, was thus bought by Google for US $ 1.65 billion in October 2006, at which point some 100 million videos were being viewed each day. Such potential has not yet, though, been widely used for development purposes, with a search on YouTube in December 2006 listing only 214 videos for the words 'Africa' and 'development' (22 December 2006), including a 7-minute video entitled "Achieving the Millennium Development Goals" (http://www.youtube.com/watch?v=ReRx12QUv54, accessed 22 December 2006) which had at that date been viewed by 1400 people. By 7 January 2008, there had been a considerable increase in interest in development agendas, with 948 videos being revealed in a search for 'Africa' and 'development', and 9,670 people having viewed the MDG video. These figures nevertheless remain paltry beside the 60,000 videos posted with reference to George Bush or 81,4000 on Britney Spears; there were also 28 videos on ICT4D.

The production of multimedia resources has enormous potential for development practice. Paradoxically, though, much of this potential has yet to be realised in full. In part this reflects the expense of developing and editing really high quality multimedia resources. However, it also reflects a general focus on the use of text based resources in most learning and teaching environments. There are many advantages that film, video and audio can bring to information sharing and knowledge creation in the development context, among the most important of which are: their ability to incorporate several senses in the learning experience; an opportunity to provide information that cannot easily be shown in other ways; the use of a story line that can link issues to emotions; their ability to be shown on widely available television sets or even projected onto sheet hung between trees; and their use as a catalyst for discussion.

However, traditional film and video tape production and storage have four main drawbacks: cameras, processing equipment and projection facilities have tended to be very bulky and not easy to use; the materials and equipment are relatively expensive; the actual video tapes or films do not last long in harsh environments; and they are not very conducive to interactivity. This last point arises because traditional films and video tapes run in sequence from beginning to end, and it is not easy to search for particular scenes or sequences on them that participants might want to return to for discussion. Many of these issues have now been overcome by the introduction of digital technologies. Cameras today are much cheaper and smaller, there are no expensive film processing costs, relatively little training is required for people to learn how to edit digital video on a computer, CDs or DVDs are cheap and robust in harsh environments, and content is readily searchable and playable for group discussion purposes.

There are many instances of the good use of traditional film and video resources in development practice, typified for example by the 20 minute video *Understanding Livelihoods: Complexity, Choices and Policies in Southern India* produced by Catcher Media for DFID (High *et al.*, 2001; see also http://www.livelihoods.org/info/tools/UL_video.html, accessed 5 May 2007). This was specifically designed as a catalyst for discussion about sustainable livelihoods issues among development professionals in the NGO and government sectors working at both policy and field levels. Traditional film and video tape can, though, also be made available in newer formats, as on CDs or streamed over the internet (see GTZ and inWent, 2003). A good example of this is the film *A Mother's Story* made by the Mediae Trust in Kenya in 2000 for the National Malaria Control Programme, so that it could be shown at the annual Roll Back Malaria Global Partners Meeting in Geneva that year. This was subsequently incorporated into a CD of resources on malaria diagnosis and treatment being developed by Imfundo's partners, and particularly Atticmedia, for the Tanzanian Ministry of Health, and again supported by DFID. Eventually, in 2004, the same film was incorporated into the ICT4D Collective's website, and is now accessible online at http://www.gg.rhul.ac.uk/ict4d/Malaria.html (accessed 4 May 2007). This now enables online users to access the six short video clips, and to discuss questions about the material that they see and hear.

It is important to distinguish between two different types of use of film, video and audio resources: those developed and made by external agents for a particular development learning or dissemination purpose; and those used in a participatory way as part of a self or communal learning process. Both have important values in development practice. The former category includes most materials made as contributions to the enhancement of development practices as illustrated in the previous paragraph. As Bohmann (2003, unpaginated) has commented, 'These media are usually used in group work to arouse interest in a topic, to transfer certain information, and as a didactic instrument at the micro level'. They can also be used to raise general awareness of development issues among people in richer countries and more privileged societies. However, an alternative and very important use of video, and sometimes also audio, is in participatory methods (see White, 2003, notably the regular monitoring of performance (Lunch 2007). The use of video by teachers to monitor their own teaching performance, or by doctors in the way in which they respond to patients, can thus be extremely useful in enhancing the delivery of education and health provision.

3.2.3 The power of the internet and the World Wide Web

It is important to distinguish between two, often confused terms, the internet and the World Wide Web (or Web). The internet is essentially a connection of inter-connected computers, or a network of networks, whereas the World Wide Web is the body of resources accessed by hyperlinks, commonly called Uniform Resource Locators (URLS), that is accessed over the internet. As the number of computers increases, so too does the power of the internet, but only if these computers are effectively and efficiently connected. Hence the amount of computer memory and the channel capacity between computers, often referred to as the bandwidth, are absolutely essential components of the internet. The modern Web provides the world's greatest source of information storage, combining the memory contained in all of the computers of the internet. Moreover, because anyone with a computer terminal and the appropriate software can now upload material, it has transformed traditional processes of information capture, sharing and retrieval.

The internet consists of the collective, publicly accessible, computer networks around the world (Abbate, 1999). For it to function at all, some computer systems, known as servers, need to be kept running permanently, so as to provide the required services to other computers within a given network that wish to access them. These servers can be of many different kinds, but include mail servers that handle e-mails, application servers that run applications, and file servers that store files and databases. In essence, the internet then functions by enabling data to be transmitted in 'packets' through a range of mechanisms, mainly through wires, fibre optic cables or wirelessly (see Chapter 3.3). So that users can know what data they want to access, a system of rules for addresses has been constructed that enables computers to communicate, and this is known as the Internet Protocol or IP; each computer is allocated a unique IP address that enables it to communicate with any other computer on a network. The dominant Internet Protocol version in use for the internet today is IPv4, which was released in 1981 (ftp://ftp.rfc-editor.org/in-notes/rfc791.txt, accessed 31 January 2007) and uses 32-bit binary addresses (usually written as four groups of decimal numbers each representing eight bits as in 213.207.6.42) enabling it to have some 4 billion potential addresses. With the rapidly increasing number of computers, it has been necessary to change this, and its successor is likely to be IPv6 which uses 128-bit addresses, and therefore has the potential for 3.4×10^{38} addresses (Loshin, 1999; Miller, 2004). In enabling computers to access data from other computers, it is crucial for data packets to be routed efficiently, and hence much attention has been paid, especially by companies such as Cisco Systems, to the design and development of 'routers' that enable path selection to be optimised.

Much of the early development of the internet (Leiner *et al*., 2003) and its associated protocols and technologies was undertaken within the Defense Advanced Research Projects Agency (DARPA) of the US Department of Defense, evolving from the ARPANET project in the late 1960s. It is therefore no coincidence that most of the control of the internet remains in the hands of institutions based within the US. For the internet to function effectively, it is crucial for there to be some systematic way of assigning IP addresses. This concept was embedded in the early work of

DARPA, and by the late 1980s the US government had established an Internet Assigned Numbers Authority (IANA, http://www.iana.org) to fulfil this role. Then in 1998 the Internet Corporation for Assigned Names and Numbers (ICANN, http://www.icann.org) was established as a non-profit corporation based in California to manage these and other internet-related functions, particularly the assignment of domain names and IP addresses. This dominance of the US in internet governance has become a topic of considerable debate, and was one of the key issues discussed during the Tunis phase of the World Summit on the Information Society in 2005 (see Chapter 4) (Huston, 2005).

[TABLE 3.2 HERE]

The amount of traffic using the internet has increased dramatically since its origins in the late 1960s (see *Amateur Computerist*, 2007). By the start of 2008, it was estimated that there were more than 1.26 billion users, representing more than a doubling in use since 2000 (Internet World Stats, http://www.internetworldstats.com/stats.htm, accessed 7 January 2008). However, as Table 3.2 starkly emphasises, such usage is highly variable across the world. Asia, for example, has the most internet users in the world, but this largely reflects its huge population, of which only 10.5% are actually internet users. In contrast, North America has the highest percentage of internet users amongst its population (69.4%), but the lowest usage growth rate (114.7%). Africa, with only 3.5% of its population using the internet, had the highest growth rate of 625.8% between 2000 and 2007. The fundamental point to note about these figures is that internet access is still very low in Africa, Asia, Latin America, the Caribbean and the Middle East, and even within these regions it is primarily the rich who benefit most from its potential. Whilst many innovative ICT4D projects have therefore been developed, and the pace of change is accelerating rapidly in these regions, the fundamental conclusion that must be drawn is that at present other technologies have much greater potential to deliver the information and communication needs of poor people. Moreover, Table 3.2 emphasises once again the enormous divide that exists between the richer and poorer regions of the world in terms of internet usage. If we are truly to aspire to digital equality, and a situation where poor people can indeed be empowered through the use of the internet, we still have a very long way to go. Indeed, these figures are a shocking reminder that however much work has been done over the last decade in seeking to implement beneficial internet based learning and health initiatives, these can only scratch the surface of poverty and marginalisation in the poorest regions of the world. It is not only at a global level that there are striking differences in internet usage. As Figure 3.3 illustrates, even within the poorest regions of the world, there are vast differences. While north African countries such as Tunisia (9.2%), Egypt (6.9%) and Algeria (5.7%) generally have between 5% and 10% of their populations being internet users, this figure falls to as low as 0.03% in Liberia, and most sub-Saharan countries have less than 1% of their populations using the internet (www.interworldstats.com, accessed 31 January 2007). Moreover, even where there is access, the quality of access may be extremely poor, reflected in slow download and upload times, unreliable connectivity and high cost. Only when the internet can be reliably available at a price that poor people can afford will it become a powerful tool for their empowerment.

[FIGURE 3.3 HERE]

3.3 The Physical Infrastructure

All communication systems require a physical infrastructure to be in place to generate and receive signals, and there must also be a source of energy to enable such signals to be transmitted. At the most basic level, human beings have mouths and ears (physical infrastructure) to create and receive sounds, and they must be alive (energy) to make these organs function. Simple technologies, such as two metal cans with a stretched piece of string or wire between them, likewise enable sounds to be carried from one place to another. Without such infrastructure, none of the complex systems of computers, radios or mobile phones that exist today would be able to deliver their appropriate functions. The provision of physical infrastructure, though, is often one of the least considered aspects of ICT4D programmes. All too often, the infrastructure is either taken for granted or ignored.

On more than one occasion, ambitious programmes have been developed to introduce computers into schools, only for it to be realised that the absence of electricity has meant that only a few such schools would actually be able to benefit. Indeed, much of the inequality in the distribution of the benefits of ICTs can be attributed to a spatially differentiated supply of basic infrastructure. One of the reasons why China's initiatives to introduce educational television into schools have, for example, been so successful, is that they were preceded by a very substantial programme of rural electrification (Pan *et al.*, 2006) with the launching of appropriate satellites then enabling television signals to be relayed throughout the country. In contrast, the lack of a basic and reliable electricity supply across much of Africa today remains one of the greatest handicaps to the continent's development.

In exploring the most relevant infrastructural needs, it is useful to distinguish between two main different types of media, those that use wires or cables and those that do not, and within the latter group it is common to differentiate between terrestrial wireless technologies and the use of satellites. In addition to the actual media used, this section of the chapter also pays explicit attention to the energy needs associated with ICTs, and questions surrounding their sustainability. At the beginning, it is important to recognise that the choice of infrastructure depends on many factors, including the physical environment in which one is seeking to provide a solution, the distances involved, the security that is required, as well as the need for flexibility in response to future changes in capacity, and the regulatory environment within which the technology is to be deployed. This is well illustrated by Table 3.3, which provides an overview of the advantages and disadvantages of the different types of media used in assembling and cabling Cisco routers (McQuerry, 2004).

[INSERT TABLE 3.3 HERE]

3.3.1 Cables and wires

Until recently, most telecommunication systems have used wires as the medium to connect transmitters and receivers using analogue systems. Voice was converted by a microphone to electrical signals that were transmitted down a wire to a speaker that would then convert the waves back to sound. The original telephones were connected in pairs, but as demand grew individual telephones were connected to exchanges, so that they could then use shared lines between exchanges to connect to any number of other telephones. Initially human operators would connect people to those with whom they wanted to speak. However, with advances in telecommunications technology by the mid-1960s electrical switches controlled by pulses sent by the caller's phone connected the user's line with the number required. As the number of phones expanded, so too did the amount of cable carried either underground or on telegraph poles stretching across the landscape. Long distance telephony between continents was enabled by the laying of oceanic cables, the first of which was completed in 1858 between Ireland and Newfoundland.

The earliest telephone lines were simply wires made of iron or steel. These rapidly corroded, and it was not until the introduction of hardened copper wires in the late 19th century that a successful basis for telephony was established. Alexander Graham Bell then introduced a two-wire circuit to replace the single grounded wire system in 1881, and in essence this principle remained the basis of most telephone systems throughout the 20th century, although numerous subsequent innovations enabled increasing capacity to be carried. By the late 20th century, the introduction of digital systems again transformed telephony, permitting digital signal processing over existing twisted-pair telephone wires. This enabled people with modems to connect these to their normal telephone lines to carry digital signals as well as voice. Digital Subscriber Lines (DSL), using frequencies above those needed in voice telephone conversations, in conjunction with standards and protocols, known as Integrated Services Digital Network (ISDN) systems, were then introduced to enable complex voice, text and video over normal copper telephone wires. In particular Assymetric Digital Subscriber Line (ADSL) technology, with flows of data greater in one direction than the other, have now enabled copper wires to retain their place in the market.

As with all technologies, copper wires and cables have both advantages and disadvantages. With copper prices being relatively cheap, and with new algorithms and hardware enabling ever-faster transfer of voice and data, it is likely that traditional telephone cables will continue to be used in this way for some time to come. However, with the dramatic expansion in mobile telephony and in areas where existing cables have not already been laid, it may well be that alternative solutions will become much more popular. This is especially so given the ease with which copper cables can be tapped, and the extent to which they are stolen in many poor countries (Mbarika, 2002).

Fibre optic technology has recently provided a fundamental challenge to telecommunications systems based on copper wires. It has the particular advantages of being able to carry very much more traffic and of being much less able to tap into than traditional copper cables (see Table 3.3). The first practical applications of fibre optics in the communications industry, based on the passing of light through a glass or plastic fibre, occurred in the 1970s, and the field has expanded very rapidly since (Hecht, 2002). The first Transatlantic cable using fibre optics went into operation in 1988, and during the 1990s the introduction of photonic crystal fibre, which uses diffraction from a periodic structure rather than total internal reflection to transmit light, led to a considerable increase in capacity. Fibre optics have four key advantages over copper cable: they have much less loss on transmission, and therefore permit long distances to be covered without repeaters or amplifiers; they have very much greater data-carrying capacity or bandwidth; when laid alongside each other, they do not suffer from the 'cross-talk' associated with copper cabling; and they are also very much lighter. Although the costs of production and deployment of fibre optical cable are higher than for traditional copper cabling, these advantages mean that many of the richer countries of the world are now providing broadband access with previously undreamt of capacity through the use of fibre optics. Advocates such as Jean-Michel Billaut (http://billaut.typepad.com, accessed 26 March 2007) have encouraged whole communities, as in Pau in southern France, to adopt fibre optic solutions, so that they have the bandwidth to deliver a new range of services including video conferencing, DVD quality streaming and interactive three-dimensional services, as well as more traditional data and telephony functions. As yet, though, only a very small percentage of the total fibre-optical capacity in the world is used, and it is likely to be several more years before it comes to replace traditional copper cabling. If sufficient funding can be made available, though, there is a strong case for poorer countries of the world to install fibre optic cables from the very beginning in areas that are not yet served, so that they will have the bandwidth capacity for the delivery of services in the future as they become available.

An alternative wired solution to the provision of digital connectivity is through the use of electric power lines, known as power line communication (PLC) (see for example, International Powerline Communications Forum http://www.ipcf.org and http://www.powerlinecommunications.net, both accessed 7 January 2008; Dostert, 2001). In essence, this can provide communication links wherever electricity flows, by impressing a modulated carrier signal onto the wiring system. This can apply equally through the wiring system of a house, or across a national electricity transmission network. Such systems eliminate the need for separate digital wiring, and have the distinct advantage that they can provide broadband connectivity wherever there are power lines (BPL – Broadband over Power Lines). However, the lack of standardisation in the provision of electricity services, the noisy environment of power lines, and existing regulatory frameworks have all limited the expansion of BPL to date. In the future, particularly in rural areas, there is nevertheless potential for power lines to provide a service backbone with wireless systems then providing wider connectivity from transmitters along the route of a power line (see Section 3.3.2 below).

3.3.2 Wireless solutions

Wireless technology, at its simplest, provides communication without the need for the medium of cables and wires. Instead, it uses parts of the electromagnetic spectrum to transmit signals, and is often divided into three types: short range communication between devices; broadcast distribution; and last-mile solutions (Panos, 2006). Wireless technologies use 'radio' frequencies, which are defined as those electromagnetic waves that lie in the range of 3 Hz to 300 GHz. These can be broken down into specific groups according to their frequency and wavelength. As frequency increases, wavelength decreases, and these properties mean that different parts of the spectrum are suitable for particular purposes. Thus very low to extremely low frequencies between 3 Hz and 30 KHz, with wavelengths of 100,000 km to 10 km, often known as sonar (sound navigation and ranging), are used for communicating with submarines and geophysics. Radio and television broadcasting generally uses the range from 30 KHZ to 300 MHz, and microwave ovens, mobile ‘phones, wireless Local Area Networks (LANs) and Bluetooth use ultra high frequencies of 300-3000 MHz, with wavelengths generally between 1 m and 100 mm. In essence, such waves are produced by supplying an alternating current to an antenna, and they can then be picked up by a receiver which converts them once more into sound, pictures or data. Three general principles underlie the use of these different spectra:

- ‘the longer the wavelength, the further it goes;
- the longer the wavelength, the better it travels through and around things;
- the shorter the wavelength, the more data it can transport’ (Alchele *et al.*, 2006, p. 16).

Thus radio broadcasting uses longer wavelengths than television since it needs to send less data, and digital broadband which needs to transport very large amounts of data uses much shorter wavelengths. At present, there are two main wireless technologies of interest for data transfer: Wi-Fi (first standards in 1997) and Wi-MAX (since 2001). Until recently, there were three main Wi-Fi (Wireless Fidelity) standards in use: 802.11 b and g, for frequencies between 2.412 and 2.484 GHz, and 802.11 a, operating between 5.170 and 5.805 GHz (Gast, 2005). These were largely replaced in 2007 by 802.11-2007. For WiMAX (Worldwide Interoperability for Microwave Access), the original standard was 802.16 for the 10 to 66 GHz range, and this was updated in 2004 (802.16-2004, also known as 802.16d) to add specifications for the 2 to 11 GHz range, being further amended in 2005 to the 802.16e-2005 standard (Andrews *et al.*, 2005).

All wireless technologies need some kind of transmitter, or antenna, as well as a receiver. One of the key difference between radio and television broadcasting on the one hand, and wireless digital technologies on the other, is that because of their longer wavelengths the former can pass around obstacles, whereas the latter generally cannot. This is why, when designing wireless networks for high bandwidth data transmission, it has until recently been essential to have line-of-sight visibility between the antenna and the receiver. The longer wavelengths of the WiMAX standard, are now, though, making this less of a restriction. In designing wireless internet networks, three different configurations are often identified: point-to-point, where a single remote site is linked to a central hub; point-to-multipoint, where a central hub links to a number of remotes; and multipoint-to-multipoint, where all of the points can interconnect with each other. Each of these alternatives can have applications in different circumstances depending on the particular needs of the user, and the constraints placed on them. Likewise, it is important to emphasise that the initial internet connection to the central antenna can be provided in a variety of ways, either through cable or via satellite.

Wireless technologies have immense potential in poor countries and communities, especially where good line-of-sight visibility is possible (for a wide discussion see Castells *et al.*, 2007). In flat areas, a mast can be erected, and in mountainous parts of the world point-to-point connections can be provided by locating antennae on the highest ground. Where there are fears over theft, it is generally also far easier to protect antennae than it is to keep an eye on lengths of cabling over long distances. There are, though, different security concerns with respect to wireless, because the networks are based on a shared medium and their traffic is therefore visible to all users. Where data security is of importance, it is thus essential to use encrypted systems and to maintain effective authentification procedures. Another critical factor that needs to be considered in the use of wireless is the regulatory environment in place not only within a country, but also globally. Without a clearly defined set of rules to control the use of different wavelengths, only those with the most powerful transmitters, or in closest proximity to an antenna, would be able to send or hear a signal. Hence, complex systems of regulation and standards have been put in place to enable these issues to be managed effectively (Bekkers and Smits, 1999; see also Chapter 4).

There are important differences between the Wi-Fi and WiMAX standards. In essence, signals from all those wishing to use with Wi-Fi the must pass through a wireless access point on a random access basis, whereas WiMax uses a scheduling algorithm which not only makes it more stable but can also ensure that appropriate bandwidth is allocated to control the quality of service delivered. Generally speaking Wi-Fi is also more appropriate for small networks requiring shorter ranges of several hundred metres, as within a single organisation. In contrast, WiMAX provides solutions over several kilometres typically with a point-to-point connection between an Internet Service Provider and an end user. As the WiMAX Forum comments: 'WiMAX is a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to wired broadband like cable and DSL. WiMAX provides fixed, nomadic, portable and, soon, mobile wireless broadband connectivity without the need for direct line-of-sight with a base station' (http://www.wimaxforum.org/technology/, accessed 9 January 2007).

3.3.3 Satellites

The use of satellites is a central part of modern wireless technology. However, in addition to providing means for disseminating radio and television broadcasts widely across the globe, they have increasingly also been used for telephony and multimedia data services. Satellites provide a very important mechanism for enabling digital connectivity in parts of the world poorly served by traditional wired infrastructures, but the initial cost of launching them means that the provision of these services by satellite is by no means a cheap option. Vanbuel (2003, p. 7) has highlighted five key advantages that satellites can provide:

- 'Reception is possible with small antennae';
- It is possible to have instant connection almost anywhere within the footprint of a satellite, without the need for any cabling or other terrestrial infrastructure;
- The equipment that consumers need to purchase is relatively low-cost

- ‘Internet connectivity can be combined with traditional broadcasting technologies such as digital TV and Radio, enabling content providers to select the most appropriate delivery means according to the type of content’; and
- The use of satellites for one-way multimedia push services such as data broadcasting is very efficient, because they do not require a modem and internet connection for the return link.

In essence, satellites reflect wireless signals from a transmitter on the ground, the uplink, to receivers somewhere else in the world, the downlink. They do this through transponders, which receive the signal from the transmitting earth station, translate them, and then relay them to an antenna that transmits them back to earth. Satellites in general have several transponders on board, and they can therefore deliver various communication channels together at the same time. Broadly speaking, there are two main kinds of satellite: geosynchronous ones that travel 36,000 kms above the earth, making one orbit every 24 hours, thus appearing stationary above a particular part of the earth’s surface; and those that travel much faster at less distance from the earth in either medium or low orbits. The advantage for users of geostationary satellites is that earth stations can be fixed in their orientation to pick up their signals, but these satellites require more power to transmit the signal than do low or medium orbiting satellites that are nearer the earth’s surface.

One particular application of satellite technology, Very Small Aperture Terminal (VSAT) systems, has become particularly popular in recent years to provide communication services for a range of uses, from corporate banks to rural telecommunications. VSAT solutions, using dish antennae less than 3m in diameter, ‘provide very efficient point-to-multipoint communication, are easy to install, and can be expanded at low extra cost’ (Vanbuel 2003, p. 31). VSAT is very flexible, and can provide any digital services, including telephony, broadband internet, and video-conferencing. For this reason, they have become an increasingly popular ‘development’ solution, exemplified in contexts as diverse as the World Bank’s

Global Development Learning Network (GDLN) (http://www.gdln.org, accessed 3 May 2007) which now has some 120 learning centres in nearly 80 countries, and the contracts won by Gilat (http://www.gilat.com, accessed 28 October 2006) for providing telecommunication services in African countries such as South Africa, Rwanda and Kenya.

The type of equipment needed on the ground to receive satellite signals varies with the type of intended usage. Key considerations for users of satellite services are the cost of the ground equipment and the amount paid for the services provided. Cost calculations can be extremely complex (see Vanbuel 2003), and it has as yet proved difficult to find models that enable poor communities without the means to pay for the services offered to benefit from the undoubted potential that satellite technology can provide.

3.3.4 Energy and environmental sustainability

None of the above elements of the infrastructure required for ICT4D would be possible without electricity. At a basic, but nevertheless fundamentally important level, the distribution and availability of electricity are central to all considerations of ICT4D. This applies as much to the power needed to make a radio work, as it does to the energy requirements of a group of servers in the headquarters of an international bank. Unlike many other industrial sectors, ICTs are almost completely dependent on electricity. Other fuels, such as oil and gas, or the energy provided by flowing water or wind, cannot directly power a computer or television transmitter; they first need to be converted into electricity. It is not easy to obtain data on electricity availability globally, but consumption and availability are closely related, and Figure 3.4 therefore provides an important reminder once again of the dramatic differences between electricity supply in different parts of the world. Despite an almost six-fold increase in electricity generation since 1971, Africa still only produced around 540,000 GWh in 2004, representing a mere 0.62 MWh per person, compared with around 14.25 MWh per person in the USA (figures derived from http://www.iea.org, accessed 1 February 2007). It is not only at a global scale that these issues make a difference, because in most poor countries there is also a marked difference between electricity supply in urban are rural areas. As Bertolini (2004, p. 3) has commented, 'despite the investments and government-driven telecommunication development programs, the supply of phone or Internet services in rural and remote areas is still hampered by underinvestment and lack of electricity: approximately 60 percent of Africa households do not have access to their national grid'.

Without electricity there can be no ICT4D. It is, nevertheless, possible to generate electricity in a variety of ways, and recent innovations with solar power and the use of human energy, as with 'wind-up radios' (see, for example, http://www.freeplayenergy.com/, accessed 20 February 2007), illustrate the diversity of solutions that are available, especially to some of the most marginalised communities. Central to any consideration of electricity supply in the poorer countries of the world is not only its presence or absence, but also its reliability. For effective implementation of ICT4D programmes, it is essential that there is an appropriate and consistent source of electricity, and this usual means that back-up generators or some form of energy storage, is required. Broadly speaking it is possible to distinguish between four main scales of electricity supply for ICT4D: national mains supplies, or the electricity grid; locally produced electricity from solar, wind, water, and human energy; generators producing electricity from fuel such as oil or natural gas for specific organisations or institutions; and batteries, both rechargeable and otherwise. One of the fundamental difficulties in delivering ICT4D projects at a large scale is that these almost always rely on a mains supply. Using solar power at a single school level is, for example, a costly solution. Nevertheless, as Greenstar (http://www.greenstar.org/, accessed 1 February 2007) have shown, it is possible to build effective solar-powered community centres that deliver electricity, purified water, health and education information, and a wireless internet connection as illustrated in their projects in villages in Jamaica, India, Ghana and Brazil. One of the advantages that many of the poorer countries of the world located between the Tropics possess is abundant sunlight, and if photovoltaic technology can increase in efficiency and decline more rapidly in cost in the future then it may offer a viable solution for implementing ICT4D initiatives in locations not served by national grids.

Few initiatives have yet experimented with the use of locally produced wind and water power to provide electricity to marginally located ICT4D programmes, but the potential of these sources of energy, especially in mountainous and coastal regions is worthy of greater investigation. Critical to such initiatives is the need to have energy efficient batteries that can store the electricity that is not immediately used, thereby helping to provide greater continuity of supply. At a smaller-scale, the Freeplay Foundation (http://www.freeplayfoundation.org/, accessed 1 February 2007) has been developing and implementing human powered electricity generation, such as the Weza, a foot-powered portable energy source, that can be used to provide sustainable rural energy solutions for ICTs (see Case Study below)

[HOLLOW CASE STUDY ON THE FREEPLA FOUNDATION here]

Any discussion of energy would be incomplete without some mention of the environmental sustainability issues surrounding the use of ICTs. There is no doubt that the dramatic global increase in the use of ICTs has led to a considerable surge in energy demand. Moreover, many of the components used in computers are highly toxic and until recently little attempt has been made by suppliers to minimise their use or to initiate recycling programmes (Kuehr and Williams, 2003). Indeed, there have been very few rigorous attempts to analyse the total environmental impact of ICTs. Such research would need to factor in such things as the costs of launching and decommissioning the satellites used for telecommunication purposes, apportioning the full costs of energy infrastructure provision, and the impacts that these technologies have had on human physical mobility through, for example, the use of video-conferencing instead of face-to-face meetings. The advent of campaigning organisations such as AsYouSow has, though, recently begun to have some impact on this, with Apple Computers, for example, announcing in 2006 that it would implement a free recycling programme for customers who purchased a new computer (http://www.asyousow.org/sustainability/ewaste.shtml, accessed 1 February 2007). Civil society organisations such as Computer Aid International (http://www.computer-aid.org/, accessed 1 February 2007) and Digital Links International (http://www.digital-links.org/, accessed 1 February 2007) have also begun to provide refurbished computers for use in poorer parts of the world, and there is clearly a demand for such products. Nevertheless, there is considerable debate about the costs and benefits of such initiatives. There are both environmental and socio-economic arguments in favour of the use of refurbished computers. On environmental grounds, the use of refurbished computers prolongs the life of perfectly usable hardware, and thus helps to reduce the wastage resulting from the obsolescence caused by the rapid rate of technological innovation in the ICT industry. However, even here, it can be argued that the shipping of old computers from the richer countries of the world to the poorer ones is actually also shifting the responsibility for their eventual disposal to those who can least afford it, especially since older computer parts are also more likely to fail than younger ones. On the socio-economic side, there are likewise strong arguments that giving poor people the opportunity to learn how to use computers is of real benefit, regardless of the quality of the actual computers themselves. Much high quality educational software, for example, can run on very basic computers, and does not require the use of the latest high specification and expensive machines. On balance, provided that the quality of the refurbished computers is of a high standard, and particularly where people in recipient communities enhance their own skills and expertise by undertaking the refurbishment work themselves, there does indeed seem to be some value in such initiatives. However, as a report by SchoolNet Africa (2004) summarises, many well-meaning such initiatives have failed because of faulty computers, a lack of planning, and poor quality of post-supply support. In contrast, where refurbishing and maintenance skills can be developed within Africa, where the schemes are co-ordinated and implemented coherently, and where in-school ICT capacity is explicitly enhanced, then they can indeed bring benefits to people who could not otherwise afford to access computers.

3.4 User Interfaces and Information Sharing

It is essential for people to have some kind of interface if they wish to gain information and communicate with each other. Whereas in the past these types of interface tended to be distinct, the advent of digital technologies has brought them ever closer together. Until the advent of ICTs, the only way in which people could communicate synchronously was by actually meeting face to face. The use of fixed line telephones transformed this situation, and during the 20th century they swiftly enabled people with access to them to communicate with others in any part of the world. Nevertheless, telephones were rarely used primarily to gain vast amounts of information; their fundamental purpose was to enable two people to communicate effectively together at a distance. In contrast, televisions were used to receive information and entertainment; few people ever imagined that they could be an interface for two-way communication. Today, Voice over Internet Protocol (VoIP) and wireless technologies have enabled computers to become hugely powerful interfaces both for the gathering of information and also for communication purposes (see for example, http://www.skype.org, accessed 8 January 2008). This convergence of technologies has had a profound impact on human society, but remains spatially constrained. For many of the world's poorest people, telephones, radios and computers remain distinct and separate. This section therefore continues to draw a distinction between these main types of user interface.

3.4.1 Telephones

Fixed line telephones dominated the world of telephony for most of the 20th century. Although radio was in use as early as the 1920s to enable communication on trains and with aeroplanes, it was not until the 1960s that advances in electronics enabled the first primitive mobile 'phones to be produced. These operated in a specific zone, or cell, accessible from a base station. By the 1980s, the technology had advanced sufficiently, for the first generation of commercial mobile 'phones to be produced, taking advantage of networks of cells and base stations situated relatively close together. Such 'phones, however, were extremely bulky, and it was not until the 1990s that second generation (2G) phones were introduced (commonly known as GSM), using different frequencies and much more advanced signalling between 'phones and networks, as well as improvements in battery design and circuitry that made them smaller. The subsequent dramatic rise in the use of mobile 'phones was enabled by the construction of numerous base stations to increase cell density and thus permit users seamlessly to access networks wherever they wanted to. The success of such mobile 'phones led to a plethora of new innovations and competing technologies, which in turn required a complex system of standards to be introduced to enable users to communicate effectively with each other. More recently, a desire to combine voice data with digital video and e-mail on mobile 'phones, has led to the development of third generation (G3) mobile 'phones. However, these required the use of new radio frequencies, the licensing of which in many countries has been seen by governments as a source of substantial revenue generation. The consequent high costs of implementation, as well as uncertainties over whether users actually want the services provided, has therefore led to considerable delay in the world-wide roll out of 3G telephony.

Over the last decade, mobile 'phones have transformed the world of telephony (Table 3.4), both technically and also socio-spatially (Taylor and Harper, 2003). Significantly, though, the impact of mobile telephony has been greatest in regions that previously had the lowest levels of fixed line connectivity. Thus, although Africa still has by far the lowest density of telephone subscribers, some 83.5% of all telephone lines on the continent were mobile subscribers, compared with a mere 54.8% in the USA. This indicates not only the problems and costs of instaling and maintaining fixed line services in Africa, where theft of copper cabling has been rife, but also the huge demand that exists for such communication services. These generalisations, nevertheless, hide many spatial inequalities, and as Figure 3.6 highlights, there remain huge differences in the density of mobile 'phone subscribers in different countries. Thus, in states such as Ethiopia, where the government tightly regulates the telecommunications sector, there were on average only 0.53 mobile subscribers per 100 people in 2005, whereas in South Africa the figure was as high as 71.6 subscribers per 100 people (http://www.itu.int, accessed 26 March 2007). Viewed from another perspective, the average annual cost of mobile telephony for a user in Ethiopia is approximately 1/10th of the average annual income, whereas in South Africa it is 1/150th (Vanbuel, pers. comm.). Furthermore, within most of the poorer countries of the world, rural areas still have much less accessibility than do urban areas, once again reinforcing the disadvantages between the urban rich and the rural poor.

[TABLE 3.4 HERE]
[FIGURE 3.6 HERE]

The very rapid adoption of mobile telephony in many of the poorer countries of the world, and particularly in Africa, has given rise to much interest in its use for broadly defined development purposes (see for example, Kukulska-Hulme and Traxler, 2005). Typical potential uses, for example, have been explored particularly with respect to the opportunities that they can provide for farmers to gather market information, for mobile banking, for the provision of health services, and in teacher education. Mobile ‘phones provide farmers with opportunities to gain information about the prices pertaining in particular markets, and they can thus not only circumvent the middle-men, but also direct their produce to the most profitable markets, thereby maximising their incomes. Likewise, in the field of health, patients can theoretically gain diagnoses and guidance for treatment without having to travel long distances to visit a hospital. However, despite such potential value, much evidence suggests that mobile ‘phones as yet are still used primarily for social networking rather than for any more specific poverty elimination purposes. Souter *et al*. (2005, p.8) in their major study of Gujarat, Mozambique and Tanzania, thus draw five important conclusions about the use of telephones:

- they are very important in emergencies so that people can contact one another;
- they are used widely to maintain social networks, particularly within the family;
- ‘they are valued more for saving money than for earning money’;
- richer and better educated people place more value on ‘phones than do poorer people; and
- they were ‘considered unimportant for information gathering’.

Although these conclusions relate to the use of telephones in general, and not just mobile ‘phones, they provide a salutary warning for those who see this particular technology as offering significant potential for the elimination of poverty.

This is not, though, to suggest that enabling poor people to have access to telephony is not of value in itself. As outlined earlier in this book, social networking is of extreme importance to human empowerment, and the ability of poor people to use mobile ‘phones for social and political purposes can be of real value to their sense of being and identity (see also Brown *et al.*, 2001). The political use of mobile ‘phones is especially interesting, because they can be used both by those involved in imposing the rule of law, as well as by those eager to engage in political protest. As with so many technologies, though, the ability of those in power to control and regulate their use, suggests that ultimately the advantage lies with them rather than with those eager to use such technologies to create alternative social and political structures. The richer governments of the world thus see their tracing of the global flow of ‘phone conversations as a permissible means to fight the so-called ‘war against terror’, whereas others see it as an infringement of individual human liberties. Socially, there is also much evidence that the advent of mobile telephony has fundamentally changed the ways in which people interact with each other. In the past, people had to move to fixed locations in order to communicate at a distance by ‘phone, whereas now they have the freedom to communicate anywhere that they have a signal. This has led to profound changes in social interaction, and to very different kinds of human movement in space. Furthermore, the introduction of text messaging on mobile ‘phones has also led to the emergence of entirely new modes of behaviour, especially among young people, who have developed many new and culturally distinct forms of communication (see, for example, Taylor and Harper, 2003). Castells *et al.* (2007) have thus identified six key characteristics of the new mobile youth culture that is emerging:

1. ‘Young people across the world are quick to adopt and appropriate mobile technologies….’ (Castells *et al.*, 2007, p. 167);
2. Two interconnected processes are underway: an enhancement of autonomy of youth, but at the same time little evidence of a weakening of dependency on adults;
3. It is a typical networked culture, including a new set of values and attitudes;
4. It is ‘characterised by a strong consumerist tendency’;

5. Mobile telephony plays a central role in the way in which young people construct their individual identities; and
6. There is also a new collective identity which has global relevance.

3.4.2 Computer technologies

All too often, the term 'ICT' has been used to refer almost exclusively to computers and the internet. As this book argues, however, a wide variety of other information and communication technologies are appropriate in varying development contexts. Nevertheless, the modern computer has until recently been one of the most powerful tools in transforming the ways in which we communicate, gain information and share knowledge. While computational machines have been in existence for centuries, it was only in the 1960s that the invention of integrated circuits and microprocessors paved the way for the rapid dissemination of home and workplace computers from the 1970s onwards (Ceruzzi, 2003; for timeline see http://en.wikipedia.org/wiki/Timeline_of_computing, accessed 3 May 2007). Central to the success of this transformation has been the dramatic increases in memory and processing speed referred to above in section 3.1.2. There are three main types of device associated with modern computers: the processing part of the computer itself; input devices; and output devices. Broadly speaking, the hardware necessary to make a computer function consists of the following: the motherboard, holding the Central Processing Unit (CPU) and Random Access Memory (RAM), as well as other parts such as the Basic Input/Output System; a storage device, usually known as a Hard Disk; a power supply and fan to keep it cool; video and audio cards in order to enable sound and visual displays; buses which transfer data or power between components; and a means of enabling the computer to interact with the internet, such as a modem. Input devices are becoming increasingly diverse, moving beyond the traditional mouse and keyboard, to include microphones, cameras, gaming sticks and image scanners. Output devices include screens, printers, and loudspeakers of many different varieties. Many of these can be integrated into a single device, as with Apple's 2007 range of MacBook laptops which combine a high functionality Intel Core 2 Duo processor and 80 GB hard drive, with input devices such as keyboard, trackpad, camera and microphone, and output devices such as a screen and loudspeakers. More often than not, though, the computational, output and input devices are separate, as with most desktop 'computers' which also require external power supplies.

While hardware provides the basic functionality of computers, it is the software that runs on them that enables users to take advantage of this. Most people have little knowledge of the processing functionality of computers, and their use tends to be restricted to five main functions: information gathering (most frequently on the internet, but also from data storage devices such as CDs or DVDs); communication (traditionally via e-mail, but now increasingly frequently through social networking sites, such as http://www.facebook.com, and VoIP); information processing (from basic calculations, to image processing, and database applications); the production of information and knowledge (as in the writing of reports, or graphic design and simulations); and entertainment (in the form of music, films and games).

The most important point to be made here is that the particular conjuncture of hardware and software can be configured very differently to serve the needs of varying users. In so doing, computers can be an immensely valuable tool for serving the interests of particular marginalised communities. Unfortunately, all too often, users are provided with standardised hardware and software that may not actually be of direct benefit to their development needs. For example, almost all basic ICT training programmes such as the European/International Computer Driving Licence (ECDL/ICDL) (http://www.ecdl.com, accessed 3 May 2007) focus very largely on the provision of a standardised set of 'office' packages, such as word processing, spreadsheets, databases, and presentations. While these are indeed relevant to business environments, they are invariably of little direct use to poor and marginalised communities. Teachers, for example, do not need to learn how to use the word processing functions of an Office package in order to be able to use good educational software to help students learn. Likewise, Sugata Mitra's (2003) work on minimally invasive education, has shown conclusively that young poor people can benefit from using computers placed in readily accessible places in their communities without any formal training at all (see http://www.hole-in-the-wall.com/, accessed 3 May 2007). Moreover, people with disabilities, including visual and hearing impairments, as well as those who have difficulty controlling their fine motor skills, can benefit enormously from input and output devices designed to suit their needs, such as Braille readers and specially designed keyboards and mice. Unfortunately, because of the relatively small demand for such devices, they are much more expensive that the standardised hardware available to other users.

One distinction in the architecture or configuration of computer systems that is of particular importance in the field of ICT4D is that between what are known as 'fat client' and 'thin' or 'lean' client systems. Because of the relative cheapness of personal computers (PCs), most computer laboratories in schools, libraries, universities, businesses and community centres in the richer parts of the world effectively consist of a large number of fully functional individual computers, linked together by cabling to a central server that then provides connectivity to the outside world as well as other networking services. Most of the processing is actually done on the individual desk- or lap-top computers, with data only being passed to a server for networking, and sometimes storage. This is what is known as a 'fat client' solution. However, for most uses, it is not actually necessary to have large amounts of processing within all of the computers in a lab, and a single powerful server can do most of the necessary processing for a large number of 'dummy' terminals. These terminals need only contain an input (keyboard, mouse) and an output (screen) device, as well as a limited amount of processing sufficient to run a web browser or some kind of remote desktop software. They are therefore generally cheaper, and can be of much lower specification than the desktops to be found in most computer labs across the world. Such 'thin client' architectures therefore have much potential in delivering appropriate solutions in contexts where the cost of hardware is a major concern. Other benefits that thin client systems offer for development contexts include their lower energy costs, their ability to be used effectively in dirty environments because the terminals do not have moving parts, lower maintenance costs because everything can be managed from the server, and the fact that because the terminals are of low value they are unappealing to thieves. Despite these advantages, and the ardent advocacy of organisations such as NetDay South Africa (http://www.netday.org.za, accessed 12 October 2006), it is surprising that not more thin client solutions are being promoted in Africa and Asia. In part this is because such solutions require careful and organised deployment and support, and work best where there can be institution wide implementation, which is not often possible in small-scale community-based installations.

3.4.3 Beyond laptops: convergence and the new generation of mobile devices

One of the key features of the ICT industry over the last decade has been the rapid convergence in technologies. The latest generation of mobile 'phones and personal digital devices (PDAs) for example not only provide telephony, but also contain cameras, radios, and calendars as well as having quite powerful computational abilities and connectivity to the web. Thus, since 2005, I have been able to use QuickOffice on my 'phone to run PowerPoint presentations, and I also control my laptop from my 'phone using the Clicker software produced by Jonas Salling (http://www.salling.com, accessed 4 May 2007). Moreover, in 2007 Nokia's advertising campaign for their recently launched N95 mobile 'phone describes it as 'It's what computers have become' (http://shop.nokia.co.uk/invt/0027027, accessed 4 May 2007). Such technology nevertheless comes at a price, with the N95 costing £459 from Nokia at the start of 2008 (http://shop.nokia.co.uk, accessed 7 January 2008), compared with the cost of a Dell Inspiron 6400 laptop costing only £329 (http://www.dell.com, accessed 7 January 2008). In the not too distant future it is possible to imagine a single small combined device that will have all of the basic information and communication functionality that most people will need. To date, the key restrictions on most mobile devices have been the size of the screen and the difficulties of using the keyboard. However, external keyboards are already available, and as voice controlled software improves, it is likely that inputting information will become very much easier. More of a challenge is the problem of the screen size, but even this is becoming less of an issue, as shown in the quality of videos and movies on devices such as the latest generation of iPods from Apple (http://www.apple.com/ipod/ipod.html, accessed 4 May 2007).

Already, there is a wealth of expertise on m-learning (see for example http://www.m-learning.org, accessed 4 May 2007; Attewell, 2005; Kukulska-Hulme and Traxler, 2005; Leech, 2005), but much of this remains somewhat ambivalent in terms of its real 'development' benefits for poor and marginalised communities. Enthusiasts are eager to show that it is indeed possible to use small digital devices such as mobile 'phones and PDAs to provide useful materials for teachers and learners, but their use has not yet caught on as swiftly as might have been expected. In part this can be explained by the findings of Souter *et al.*'s (2005) study which emphasise that people in Asia and Africa still tend to want to use their 'phones primarily for communication, rather than actually to gather information. It may also reflect quite simply the lack of relevant content and educational software that has as yet been made available for these devices. The size of the screens on these small devices, especially for those with poor eyesight, is nevertheless likely to remain a serious drawback to their wider use for learning purposes.

This problem of size can, however, be approached from the opposite direction by thinking about reducing the size as well as the cost of laptop computers. The One Laptop per Child initiative (OLPC) founded by Nicholas Negroponte in 2005 with a group of colleagues from the MIT Media Lab (www.laptop.org, accessed 4 May 2007) provides one such vision for the future. This initiative in part seeks to reduce the cost of specially designed laptops for children by purchasing very large numbers of parts at discounted prices. Initially, it was announced that the laptop would cost $100 but by April 2007 this figure was revised to $175, and this has somewhat reduced its appeal. Although the OLPC project specifically claims that it is an education initiative rather than a laptop one, with its goal being 'To provide children around the world with new opportunities to explore, experiment and express themselves' (http://www.laptop.org/en/vision/index.shtml, accessed 11 May 2007), its real educational usages in poor countries have also not yet been sufficiently proven, and the pedagogic model upon which it is based is seriously flawed (Kozma, 2007). Moreover, the cost of providing such laptops to every poor child in Africa would be prohibitively expensive, and there is a strong argument that such money would better be spent on training good teachers to inspire a new generation of African learners. Another similar initiative is Intel's somewhat more expensive Classmate project (http://download.intel.com/intel/worldahead/pdf/classmatepc_productbrief.pdf?iid=worldahead+ed_cmpc_pdf, accessed 4 May 2007), which is again designed for educational solutions in 'emerging markets'. Interestingly, India has rejected the OLPC project, and in May 2007 its Ministry of Human Resource Development announced that it was exploring the production of even cheaper laptops, costing at present an estimated $47 per unit, with costs likely to come down to around $10 (http://timesofindia.indiatimes.com/TOIonline/India/HRD_hopes_to_make_10_laptops_a_reality/articleshow/1999849.cms, accessed 11 May 2007). If this price mark is indeed even approximately achievable, then there do seem to be very real possibilities for extensive deployment of a new generation of small but powerful user interfaces that could become of real value to poor people and marginalised communities. We urgently therefore need to be engaging much more pro-actively in exploring the potential of these hardware 'solutions', identifying how best they might serve the needs of such communities. We must also develop and share better understandings of the total cost of deployment of such technologies, before foisting them on unsuspecting governments and educational systems.

3.4.4 Radios and television: the contribution of broadcast media

Much of the ICT4D literature and practice, while espousing the notion that ICTs are indeed much more diverse than just the use or computers and the internet, has tended to ignore the very real contribution that more traditional forms of mass media can contribute to contemporary development. It is critically important that appropriate mechanisms for delivering and receiving information are therefore developed and implemented. Indeed, it is very often the case that the most appropriate and effective means of communication rely on radio and TV, particularly since they are generally most accessible for the poorest and most marginalised communities (Figure 3.2) (Skuse *et al*., 2004; Mozammel and Odugbemi, 2005). This has been emphasised by Buckley (2000, p.185), who argues that

> It is radio which remains, today, the world's most pervasive and accessible electronic medium, and as such it potentially

> offers a bridge between the vast knowledge resources available through the Internet and the millions of people who have access to no other means of electronic communications. Community radio groups are already exploiting this opportunity through Internet-based news and information services such as the Latin American radio news agency Pulsar.

The use of mass media, notably TV and radio, for development objectives has not though been unproblematic (de Fossard, 1996). By its very definition, mass media has tended to be centrally driven, with the intention of broadcasting a particular set of message to its intended recipients. Indeed, many radio for development initiatives in Africa and Asia initially drew their impetus from the use of radio programmes in the post-1945 period in Europe to encourage a particular path of social and economic change. This was typified by the British Broadcasting Corporation's soap opera *The Archers*, which has been broadcast continuously since 1951, and was initially produced with input from the Ministry of Agriculture, designed to encourage post-war reconstruction, focusing particularly on agricultural production. Similar initiatives in the poorer countries of the world have, as Melkote and Steeves (2001, p.268) comment, been 'criticized for (i) their trivial and irrelevant content; (ii) giving rise to a *revolution of rising frustrations* in developing nations; and (iii) increasing the knowledge gap between the advantaged and disadvantaged sectors of the population'.

National centralised public broadcasting has often been used to convey particular messages through which governments have sought to influence and control their populations. Indeed, the character of broadcasting largely reflects the character of the society that produces it. Centralised states, most notably the Soviet Union and fascist Germany, thus used film and radio very directly and effectively in the 20th century to impose the will of their leaders on the minds of their populations (Taylor, 1998). Nevertheless, all publicly or government owned radio and TV broadcasting does have this potential to convey only the messages that rulers want their people to here. As Barnett (2004, p.251) has emphasised, 'Modern understandings of the relationships between media and citizenship have developed in a specific context in which broadcasting was institutionalized as an assemblage of technologies, organizations, markets and social practices that articulated two spatial scales of activity: the private domestic home and the nation state'. One of the most striking examples of the use of radio in recent times to mobilise people to do the will of their leaders is its use in the Rwandan genocide that took place in 1994. As reported by Fahamu (http://www.fahamu.org/rwanda.php, accessed 22 December 2006), 'Prior to the genocide, radio stations and newspapers were carefully used by the conspirators to dehumanise the potential victims, Rwanda's Tutsi minority. During the genocide, radio was used by the Hutu extremist conspirators to mobilise the Hutu majority, to coordinate the killings and to ensure that the plans for extermination were faithfully executed' (see also http://news.bbc.co.uk/1/hi/world/africa/3257748.stm, accessed 22 December 2006; and Windrich, 2000 for an Angolan example).

Nevertheless, as Buckley (2000, p.180) has also emphasised, 'Democracy and communication are inextricably linked, so much so that the existence or otherwise of certain forms of communications can be a measure of the limits to which democracy itself has developed or is held back'. Where the mass media is independent from government control, and ensures a plurality of voice, it can do much to provide opportunities for effective democratic processes to emerge. Moreover, local and community radio can be used highly effectively not only to convey particular information messages, but also to engage and involve people in beneficial development practices. Mano (2004), for example, has described a talk programme on Zimbabwe Broadcasting Corporation's Radio Zimbabwe service, *Chakafukidza Dzimba Matenga*, which started in 1981 and adapts past materials from Shona culture for contemporary use. In particular it seeks to reinvent a traditional *dare* through the medium of radio. In Shona culture, the *dare* was both a place and a discussion zone, involving a face-to-face gathering of people, usually men, who wanted to talk. By reinventing this modality of communication through the medium of radio, the producers have sought to engage traditional practices in the contemporary world. Likewise, in India the radio soap opera *Tinka Tinka Sukh* (Little Steps for a Better Life) seeks to promote discussions among its audiences, encouraging them to engage in collective action that will address social practices including the education of children and the use of dowries (Papa *et al.* 2000; for further examples of the use of radio, see Jayaprakash, 2000; Vaughan *et al*., 2000a, b; Villaran and Caistor, 2000). In developing such programmes, it is crucial for script writers and producers to draw upon the advantages of radio as a medium, such as its basis in oral tradition, its appeal to the imaginations of readers, and its ability to be heard en masse and individually at the same time. Likewise, they need to overcome problems with the medium, notably that most listeners tend to use radio as background, that it is usually only heard once, that there are some subjects that radio alone cannot teach, and that it can only use the medium of sound to try to create an impression of the scenes that are being created (see Fossard, 1996).

It is often thought that radio is merely a one-way transmission of information and ideas, but recent technological changes have enabled much greater dialogue to take place between the producers of programmes and listeners. Traditionally, listeners could always write in to radio programmes, but the use of telephones and the internet have now transformed the potential for interactivity in radio usage. This is typified in some of the initiatives that have sought to introduce community radio for empowering poor people. As Jewel (2006, p.5) has commented in the context of Bangladesh, 'Community Radio is radio for the people and by the people. The main objective of such a radio station is to enhance democratic process at a local level by giving voice to the voiceless. Also such an outlet helps in increasing diversity of content and information at the local level in order to promote culture. It also encourages participation, sharing information and innovation'. As he emphasises, 'Among the various mediums, it is proved that Radio is the only one, which can reach to any one and in any parts of Bangladesh. It can reach people who live in areas with no phones and no electricity. Radio reaches people who can't read and write. It can be a main vehicle to distribute information, discuss issues and define our culture' (Jewel, 2006, p.3; for a wealth of resources on community radio, see http://www.communityradionetwork.org, accessed 2 January 2007). In essence, reducing costs of equipment and an opening up of licensing to the spectrum of broadcasting airwaves have enabled local communities to produce radio programmes that can be of real relevance to their needs, be they farmers in parts of rural India, or teachers in Africa (see UNDP and VOICES, 2004a, b). However, the origin of community radio in the illegal pirate radio stations of the 1970s has given rise to some concerns over its use (Sakolsky and Dunifer, 1998). Hence, the conditions under which community radio stations are emerging are generally being very tightly regulated by national governments. In the long run, though, it seems likely that the increasing use of pod-casts and the ease of dissemination of digital broadcasting over the web will lead to much more general acceptance of the value that community radio stations can provide.

The added realism provided by the visual dimension of television has also been used extremely powerfully in delivering empowerment and development-related programmes that move beyond the mere audio of radio. However, the costs of television production and broadcasting are very much higher than those for radio. Thus, to produce a 15 minute radio-soap episode in Kenya costs around £800, whereas to produce a high quality 30 minute episode of a TV-soap costs around £20,000. Moreover, the costs of TV air-time are also very high, being £2,000 for a 30 minute slot for TV in Kenya as compared with Kenya Broadcasting Corporation's charge of around £800 for 15 minutes on their Kiswahili radio service. However, if the TV or radio programme is popular and relevant, this funding can be met by advertisers, as is the case for all Mediae broadcasts in Kenya (see Case Study). Nevertheless, the value of TV for conveying important development-related messages is particularly striking, especially since it can often be used to reach much larger audiences than radio. In Kenya, for example, three main TV stations compete for a seven million audience, whereas there are 48 FM radio stations competing for a 20 million audience.

[INSERT MEDIAE CASE STUDY]

The benefits of both TV and radio are well illustrated by the work of Soul City, which first began programmes on HIV/AIDS and mother and child health in South Africa in 1994, and now regularly reaches some 16 million South Africans. Key factors in the success of Soul City have been its multimedia format, the drama 'edutainment' format that has been sustained over time, and its thorough development process grounded in local contexts (Scheepers *et al*. 2004). Another example of the value of TV in South Africa has been *Yizo Yizo*, an educational programme first shown in 1999 which focuses on youth issues, and is described by its producers as 'a gritty, uncompromising television drama series set in a township school that has achieved record-breaking audiences and cult status among South Africa's youth. Rape, murder, prostitution, abuse, HIV/AIDS. Serious issues. We wanted to contextualize them for people with the power of music, laughter, friendship and glamour to match the gritty authenticity of the work' (http://www.thebomb.co.za/yizo1.htm, accessed 2 January 2007). As Barnett (2004, p.268) has commented, '*Yizo Yizo* stands as an example of the creative possibilities of deploying the conventions of global media cultures in progressive ways, opening up more dialogic models of media-citizenship and shifting the terms of public culture in more inclusive directions. *Yizo Yizo* is, in short, television that helps make democracy work'.

The value of TV and radio is not, though, only through the impact that it has among the world's poorer communities. Media events such as Live Aid in 1985 (Geldof, 1986) and Live 8 in 2006 (http://www.live8live.com, accessed 2 January 2007), which it is claimed was watched by 3 billion people, have a very significant effect in raising issues associated with poverty in the minds of people living in the richer countries of the world. This, in turn, contributes to the effectiveness of political campaigns, and to the policies adopted by donor countries with respect to development agendas. Nevertheless, the imagery and sounds broadcast on TV and the radio, as well as those used more widely in advertising campaigns, are far from neutral, and are chosen to represent the views of those producing the programmes. This was particularly well brought home a report by VSO (2002) that explored the impact of events such as Live Aid on the UK population's perceptions of development. This highlighted that 'Many UK consumers retain an essentially one-dimensional view of developing countries. The stereotypes are primarily driven by images of drought and famine in African countries – 'the Live Aid Legacy' (VSO, 2002, p.15). As the VSO (2002, p.15) report went on to comment, 'While these stereotypes are not completely false, they are only part of the picture. They generate and reinforce a relationship of powerful giver and helpless recipient. This relationship pigeonholes and constrains developing countries, creating the impression of a one-way, rather than two-way relationship. In turn, this limits our capacity to learn and benefit from such countries and cultures'.

3.5 Individuals and communities: debates over software and 'content'

Chapters 1 and 2 highlighted the contrasting logics of different approaches to development practice, and placed particular emphasis on the need to consider relative aspects to poverty as well as the currently more popular focus on economic growth as a solution to absolute poverty (see also Unwin, 2007). These different approaches also underlie one of the fundamental conceptual distinctions in the use of ICTs for development, one that has crucial practical implications. At the heart of this debate is the way in which we conceptualise the value of knowledge, and whether it is something that should be individually or communally 'owned' (see also Figure 3.2).

In the second half of the 20th century, there was a strong belief in much of Europe that everyone had a right to 'free' primary and secondary education, and very often also to free higher education. Moreover, this logic also underlay the rhetoric associated with the Millennium Development Goals, the second of which seeks to ensure that all boys and girls complete a full course of primary education (http://www.un.org/millenniumgoals/, accessed 11 May 2007). This is closely allied to the campaign to achieve Universal Primary Education (UPE) and Education for All

(EFA) (Bruns *et al.,* 2003; http://www.unesco.org/education/efa, accessed 7 January 2008) through the delivery of free primary education to all children in some of the poorest countries of the world, exemplified in the donor supported cases of Kenya, Tanzania and Malawi. However, the notion of 'free' education is highly problematic, because all that it really means is 'free to end user'; there is indeed a very real cost in its provision. When people still believed in the values of a welfare state and were prepared to pay high levels of taxation for the provision of appropriate services, whereby the state was indeed expected to provide free education and health to its population, such an approach was viable. However, in the present low-taxation environment, the funding of education and health systems across the world has become one of the most problematic issues facing all governments. It has also brought to the fore the very real costs associated with delivering quality services designed to provide what have increasingly been seen as fundamental human rights. This has further increased the attention that has been paid to the role that other service providers, most notably the private sector, can help with by delivering in partnership with governments. Three key variables are involved, for example, in formal educational delivery: teachers, who are often also content providers; the content, which is transformed into knowledge through the process of learning; and the places where this takes place, usually schools or universities. The emergence of new ICTs has the potential completely to transform the traditional relationships between these variables: teachers can support learning at a distance; people can learn anywhere, anytime, without needing to be stuck in a classroom or lecture hall; and 'optimal' content can increasingly be delivered in a centralised and uniform way (see also Chapter 6). This new fluidity has enabled much more complex models of educational funding to be developed, through which 'users' are increasingly being expected to pay for 'valuable' content. All of this has helped to shift the balance away from a generally accepted belief that 'knowledge' should be freely available to all, to one where it has become a commodity to be bought and sold in the market place.

This has particular resonance for any consideration of ICT4D, especially since the new technologies discussed in this chapter have the potential to make information much more accessible and more widely distributed than ever before. Two, often conflated, aspects need to be distinguished: the actual information *content*; and the mechanisms through which this is distributed, including both the *channel* and the *software*. Models and practices exist whereby all of these can be subject to payment, or can be free to end users. Moreover, discussions of such models are fraught with ideological passion, and there is as yet little agreement as to which options are actually best for different communities (see for example Rangachari, 2006: Yusof, 2007). The arguments used by those supporting proprietary solutions are usually based on a completely different set of premises than are those used by those advocating 'free' solutions.

3.5.1 Software solutions: Proprietary, Free and Open Source

For the purposes of this discussion, the term software is being used to refer to the programmes that enable hardware, including not only computers but also 'phones and other digital devices, to function effectively. For long, software designed by programmers working for the private sector has been developed and sold by companies such as Microsoft (with its Windows operating systems) that have kept the programming code confidential. The operating systems and application programmes that run on it, such as Microsoft Office, are sold at a profit to enable the programmers to be paid, new products to be developed and shareholders to reap financial benefit. In contrast, there has also been a parallel movement that has sought to develop software on a shared basis for the common good (Gay, 2002). This 'free software movement' was officially founded by Richard Stallman in 1983 when he initiated the GNU (GNU's Not Unix) Project, and it became fully functional in 1992 when Linux (developed by Linus Torvalds) was released as a completely independent and free operating system (Moody, 2002). If proprietary systems are essentially about economic gain, free software is much more of a social and ethical movement, and this distinction is one of the main reasons why advocates of these contrasting positions frequently seem to have difficulty in agreeing on any basis for reaching consensus decisions.

The creation of 'free' software has necessitated the creation of new types of license that seek to permit and how people are allowed to use it. The Free Software Foundation has thus defined four freedoms associated with it:

- 'The freedom to run the program, for any purpose (freedom 0).
- The freedom to study how the program works, and adapt it to your needs (freedom 1). Access to the source code is a precondition for this.
- The freedom to redistribute copies so you can help your neighbor (freedom 2).
- The freedom to improve the program, and release your improvements to the public, so that the whole community benefits (freedom 3). Access to the source code is a precondition for this' (http://www.gnu.org/philosophy/free-sw.html, accessed 11 May 2007).

During the late 1990s, alternative models emerged, particularly the Open Source Initiative, which has not been so opposed to proprietary software, and has instead promoted the use of the term 'open source software' as an alternative to free software. In turn, FOSS (Free and Open Source Software) and FLOSS (Free/Libre Open Source Software), the latter ensuring the incorporation of a French dimension, have emerged as generic terms to refer to alternatives to proprietary software.

The critical question for those advocating the development and use of FOSS (see for example, Ouédraogo, 2005) is how to make sufficient income to cover the labour costs involved in developing the software. Sometimes this is done by providing services in support of the programmes that have been developed, such as training or maintenance, but few such models have as yet been proven to be particularly profitable or sustainable. Much FOSS development is actually undertaken by programmers who generate income from other activities, even working for companies selling proprietary software, and do this as a 'spare-time' activity, thus in a sense self-exploiting their labour for the common good. There is extensive debate as to whether open source or proprietary software is 'better'. Advocates of open source point out that:

- it is much cheaper for end users than proprietary software, and therefore that it is particularly relevant for poorer communities;

- it is less susceptible to viruses, because potential assailants are less interested in damaging a communal project;
- it is of potentially higher quality, because a whole community of developers is there to enhance it and solve any problems that emerge, unlike the case of proprietary software which is developed by a smaller number of paid programmers;
- it has the moral high ground, because it is developed and shared for the common good rather than individual profit; and
- those involved in the community are amongst the most gifted and committed programmers and are involved primarily because of their interest rather than any income that it generates.

In contrast, advocates of proprietary software argue that you pay for what you get, and that to develop high quality software requires very considerable investment that must be paid for through an appropriate market mechanism. Moreover, they also argue convincingly that certain highly specialist types of software, especially where secrecy is involved, can only be developed through focused research and development that must in turn be paid for (see wider discussion of intellectual property rights in Chapter 1).

In trying to resolve these apparently contradictory positions, it can be argued that different types of solution are preferable in different contexts. A comparative study by bridges.org (2005), for example, has emphasised that many other factors than simply cost must be taken into consideration in reaching any decision, and local context and needs are crucially important. However, if an organisation, be it a small NGO or an entire country's education system, simply cannot afford licences for Windows operating systems, then a Linux based alternative may well make a lot of sense. Likewise, with applications software, Open Office (http://www.openoffice.org/, accessed 11 May 2007) is a completely free multiplatform alternative to Microsoft Office. Recognising this threat to their position, but also determined to help reduce the digital divide, in early 2007 Microsoft announced the release of a cut down version of its new Vista operating system and Office software called the Microsoft Student Innovation Suite, which was to be available for students in developing countries for the sum of only $3 (http://www.microsoft.com/emerging/transformingeducation/MicrosoftStudentInnovationSuite.mspx, accessed 11 May 2007). An alternative approach has been that adopted by Apple, which deliberately sought to bring together different development environments, and combined the work of its own programmers alongside the strengths of the FOSS movement in creating its Mac OS X operating system (see http://www.kernelthread.com/mac/oshistory/, accessed 11 May 2007). Crucial to the ability of users to work across several environments has been the incompatibilities involved in using different operating systems. As a result, regulators and indeed many application software developers have been keen to ensure consistency of standards across the industry, and those operating on behalf of consumers have also sought to limit the monopolistic tendencies of some global corporations. In one of the best known of these, the European Commission concluded in 2004 that Microsoft had broken European Union competition law, by leveraging its near monopoly for its operating system 'onto the markets for work group server operating systems and for media players' (European Commission, 2004).

3.5.2 Open educational resources

A similar, but distinct, debate has also arisen over the cost and means of production of content, usually with reference to educational content, but also of relevance to health-related content and indeed market information (see for example, http://topics.developmentgateway.org/openeducation, and http://www.hewlett.org/Programs/Education/OER/, accessed 11 May 2007). Between the 16th century and the early 20th century, most 'content' was developed by authors who entered contracts with publishers to produce books or articles, the income from which funded the publishing houses, defrayed the authors expenses, and if the author was lucky might generate a small profit. The expansion of higher education institutions from the mid-20th century onwards, led to an increasing number of academics being paid by the state to teach students and to publish research. This in turn generated a dramatic increase in the amount of research that was produced, with the number of academic papers published in journals now doubling approximately every ten years. The success of academic careers depended in part on publishing papers in high quality international peer reviewed journals, but the authors usually received no direct payment at all from the publishers for so doing. The publishers therefore gained an increasing amount of content for next to nothing, and were able to profit from sales of the journals to university libraries and individuals, thereby helping to fuel the cycle of knowledge production. To be sure, authors of popular textbooks were indeed able to generate additional income with the help of the publishers who paid them royalties for their books, but in large part most of the generation of knowledge was paid for by state funding of universities. This helped to inculcate a passionate belief amongst many, if not most, academics that the knowledge that they produced should be shared as freely and as widely as possible.

According to such a model, it makes sense for the state to fund higher education, because it produces 'useful' graduates, and the research that is generated can enable companies to gain a competitive edge that will enable them to gain greater profit, and thus contribute to national economic success and social well-being. However, by the end of the 20th century this model began to break down, with new ICTs enabling knowledge to be shared much more readily across the world, and a completely new international market in higher education provision also beginning to emerge. This has given rise to profound challenges to traditional models of higher education and knowledge production. In particular, authors and publishers have been forced to question the continued value of academic journals as the optimal means of knowledge dissemination for the former and as a source of profit for the latter. Likewise, universities have also had to rethink their models of learning provision, with MIT, for example, leading the way in making the content of its lectures freely available on the web (http://ocw.mit.edu, accessed 11 May 2007), and many more institutions now providing the opportunity for students to undertake courses through distance-based modalities.

These tensions have been brought to the fore in discussions about Open Educational Resources (OER), and the value of collaborative authoring projects, enabled by the use of software such as wikis that allow many users to edit content (see especially http://oerwiki.iiep-unesco.org, accessed 11 May 2007; but also Downes, 2007; Tapscott, D. and Williams, 2006). As with the debates about FOSS, those concerning OER are similarly charged, and derive from fundamentally different conceptualisations of the world: on the one hand, the individualistic view, where knowledge is seen as a commodity, the purchase of which can give rise to greater earning potential and is thus a good investment; and on the other, the view that knowledge is a collectively produced social good, that should therefore be shared communally, and indeed globally. The former is based once again primarily on economic arguments, whereas the latter is derived fundamentally from rather different social and philosophical premises.

There is much that could be said about OER, but for the present purposes I wish to emphasise three particular aspects that seem particularly pertinent to their use in the context of ICT4D. First, there is already a wealth of content that is freely available on the Web for educational and health related purposes. To be sure, not enough of this is specifically relevant and in a format usable by many poor people, and more work should be done in developing such resources by, for example, making them accessible in local languages. However, given the existence of so much material, it seems much more important to develop effective mechanisms through which the good resources that already exists can be accessed in a user friendly way by poor and marginalised communities than it is to generate yet more resources that people will have to sift through to find what they really want. Google, despite its vast resources, does not as yet provide a sufficiently useful and reliable mechanism to satisfy these needs effectively. Second, the facilitation of collaborative authoring projects through the use of software such as wikis provides a powerful mechanism through which shared understandings and communal knowledge creation can take place. Colleagues can now work together on knowledge creation from locations across the world, and if used creatively this can enable high quality material to be developed that is of direct relevance to the needs of specific communities. The key advantage of software such as wikis is that it is possible for others to benefit from the acquired wisdom of many authors, and thereby to gain a richer understanding than that provided by one person alone (Tapscott and

Williams, 2006; although see Keen, 2007 for a critical perspective). Nevertheless, a third issue with OERs concerns the mechanisms whereby authors are remunerated for their contributions. Various models exist for such provision (see for example Downes, 2007), but as yet most OER content development is enabled by people whose main source of income is generated from other means. It is all very well encouraging groups of teachers or health workers to develop and share learning resources, but if this is to be done outside normal school or hospital hours, when many such people in poor countries have to undertake other forms of employment just to make a living, some form of additional remuneration must be provided. Likewise, there is a very strong case for bilateral and multilateral donors to ensure that the results of any activities that they fund should be made available in the form of OER. Where donors finance the publication of text books in poor countries, for example, they should insist that these are made available in digital format for use in the diverse new learning contexts that are becoming increasingly accessible, even to some of the poorest communities.

4. Conclusions

This chapter has provided an overview of some of the more important technologies that can be used to address the information and communication needs of poor and marginalised communities. In conclusion, four key issues can be highlighted. First, there are many different technologies that can be applied to any one particular problem or situation. The most appropriate solution will depend on a very wide range of factors, including cost, local context, infrastructural provision, the regulatory environment, and the specific needs of stakeholders and user communities. Far too often in the past, externally imposed solutions have been imposed without sufficient attention being paid to these crucial factors, and this is one of the main reasons why so many ICT4D projects have failed to deliver sustainable outcomes. Second, and linked to this, the provision of basic infrastructure, most notably electricity but also digital connectivity, is an absolute prerequisite for the successful implementation of all ICT4D programmes. Without electricity even telephones and radios are useless. Far too often, ambitious ICT4D programmes have simply failed to recognise the huge obstacles that the lack of infrastructure creates for innovative solutions that can indeed help to empower poor people. Invariably, this is also caused by a concentration on technological solutions, rather than on the real problems that need to be addressed. Third, the processes of convergence and miniaturisation have very important implications for the sorts of hardware solutions that can best be developed for delivering effective ICT4D programmes. While the One Laptop Per Child initiative has taken a lead in publicising the potential that such provision can offer poor children, its expense and lack of a sound pedagogic model mean that it is unlikely to succeed as a sustainable global solution. However, once the difficulties associated with screen size and the inputting of content are overcome, small low-cost multifunctional digital devices will offer enormous potential for those who wish to reshape the conditions that create poverty across the world. Finally, it seems likely that debates between those advocating Open Source and proprietary software solutions will persist for some time to come, since they are based on profoundly different sets of arguments and ideologies. While many would like to claim that knowledge should indeed be a global common good to which all should have equality of access, the reality of the early 21st century is that knowledge is increasingly becoming a commodity. Those seeking to engage in delivering ICT4D agendas that will truly bring equality of opportunity to poor and marginalised communities, must therefore engage actively in arenas well beyond the realm of technology alone, and ensure that they can create powerful arguments that will shape the global social, economic and political agendas of the next fifty years.

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Table 3.1

Differences between analogue and digital electronic circuits

	Analogue	**Digital**
Noise	More susceptible to noise, because a small change in signal can represent a large change in information	Information is quantised, with information between a range of values, being interpreted the same
Precision	Generally lower precision signal because of higher noise	High precision signal is easier to achieve
Speed	Analogue circuits are much faster than digital counterparts because information is represented by a property of the signal itself	Slower, because information is represented by bits
Bandwidth	Analogue circuits have much more bandwidth and can process information more rapidly	Digital circuits are generally slower and can cope with less information than analogue ones
Design complexity	Complex to design	Easier to design
Size	Larger in size	Smaller in size
Cost	More expensive	Cheaper

Sources: derived from Beards (1996), Crecraft and Gergely (2002), Wikipedia: Analogue Electronics, http://en.wikipedia.org/wiki/Analog_electronics, accessed 14 November 2006.

Table 3.2

Internet usage statistics, 2007

	Internet users (millions)	Internet users as % of population	Internet usage growth 2000-2007	Usage as % of world use 2007
Africa	33	3.5%	625.8%	3.0%
Asia	389	10.5%	240.7%	35.6%
Australia/Oceania	19	53.5%	141.9%	
Europe	313	38.6%	197.6%	28.6%
Latin America/Caribbean	89	16.0%	391.3%	8.1%
Middle East	19	10.0%	490.1%	1.8%
North America	232	69.4%	114.7%	21.2%
World Total	**1,094**	**16.6%**	**202.0%**	**100%**

Source: Internet World Stats (http://www.internetworldstats.com, accessed 31 January 2007)

Table 3.3

Differences between networking infrastructure media types for use with Cisco routers

	Maximum segment/cable length	**Speed (Mbps)**	**Relative cost**	**Advantages**	**Disadvantages**
Unshielded Twisted-Pair Cable (UTP)	100 m	10-100	Least expensive	Easy to install; widely available	Susceptible to interference; covers limited distance
Shielded Twisted-Pair Cable (STP)	100 m	10-100	More expensive than UTP	Less crosstalk; less susceptible to EMI than UTP or Thinnet	Covers limited distance; not easy to work with
Coaxial cable	500 m (Thicknet) 185 m (ThinnetT	10-100	Relatively inexpensive,but more costly than UTP	Less susceptible to EMI than other types of copper media	Difficult to work with (Thicknet); limited bandwidth; damage can bring down network; Limited application (Thinnet)
Fibre-optic cable	Single mode: 60 km and further	10-1000	Expensive	Higher data rate than wire; difficult to tap and thus more secure; can be used over long distance; not susceptible to EMI	Difficult to terminate
	Multimode: 2km and further	100-9920			
Wireless	50 km - global	1-54	Most expensive	Does not use wires, and so can overcome obstacles and limit theft; can be used over long distances	Susceptible to atmospheric conditions

Note**:** EMI is electromagnetic interference

Source: Adapted from McQuerry (2004) (http://www.ciscopress.com/articles/article.asp?p=169686&rl=1, accessed 31 January 2007)

Table 3.4
Fixed line and mobile telephone subscribers

	Telephone subscribers per 100 inhabitants 2005	Cellular mobile subscribers per 100 inhabitants, 2005	Cellular subscribers as a % of total telephone subscribers, 2005
Africa	18.48	15.34	83.3
Americas • USA	86.14 • 130.23	53.04 • 71.43	61.5 • 54.8
Asia • China • India	38.45 • 56.53 • 12.67	22.98 • 29.90 • 8.16	59.5 • 52.9 • 64.4
Europe	125.12	85.35	67.8
Oceania	106.55	68.78	64.9

Source: derived from ITU (www.itu.int/ITU-D/icteye/indicators/indicators.aspx# accessed 26 March 2007)
Note: Figures are as given by ITU in separate tables, and do not always necessarily compute accurately

Figure 3.1
Framework for conceptualising Information and Communication Technologies

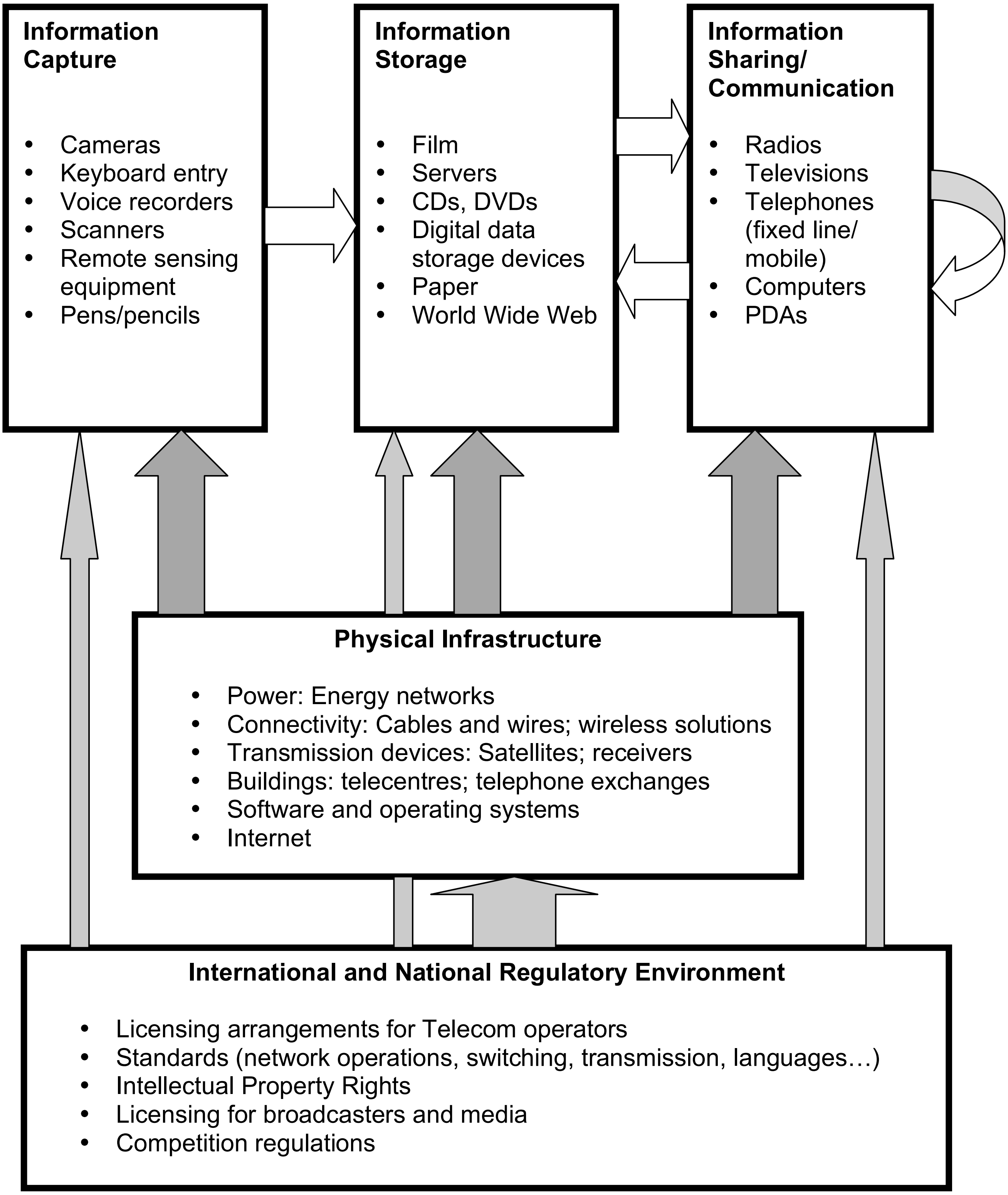
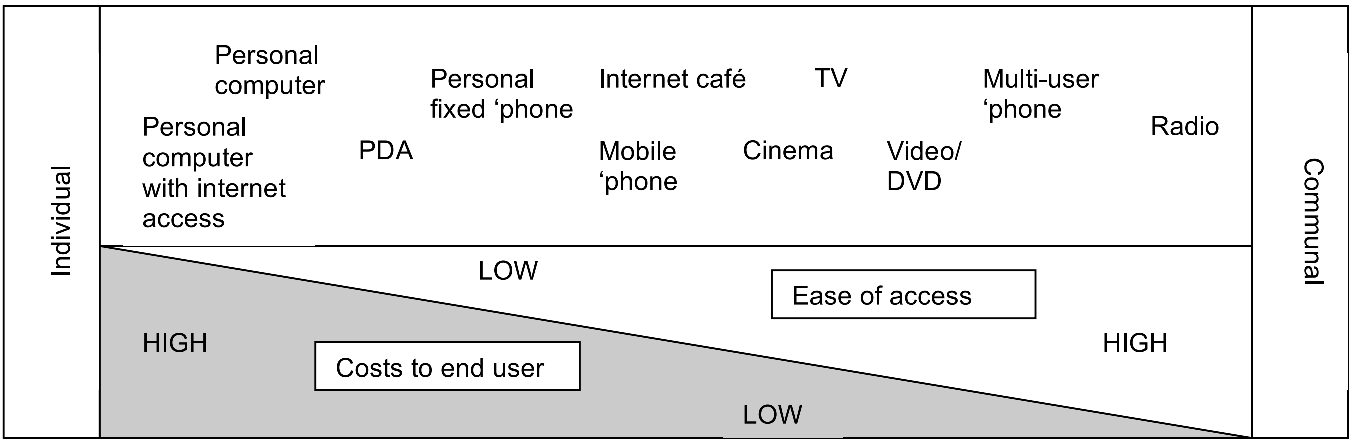


Figure 3.2
Costs to end user and ease of access of various ICTs



Source: Derived in part from Weigel and Waldburger (2004)

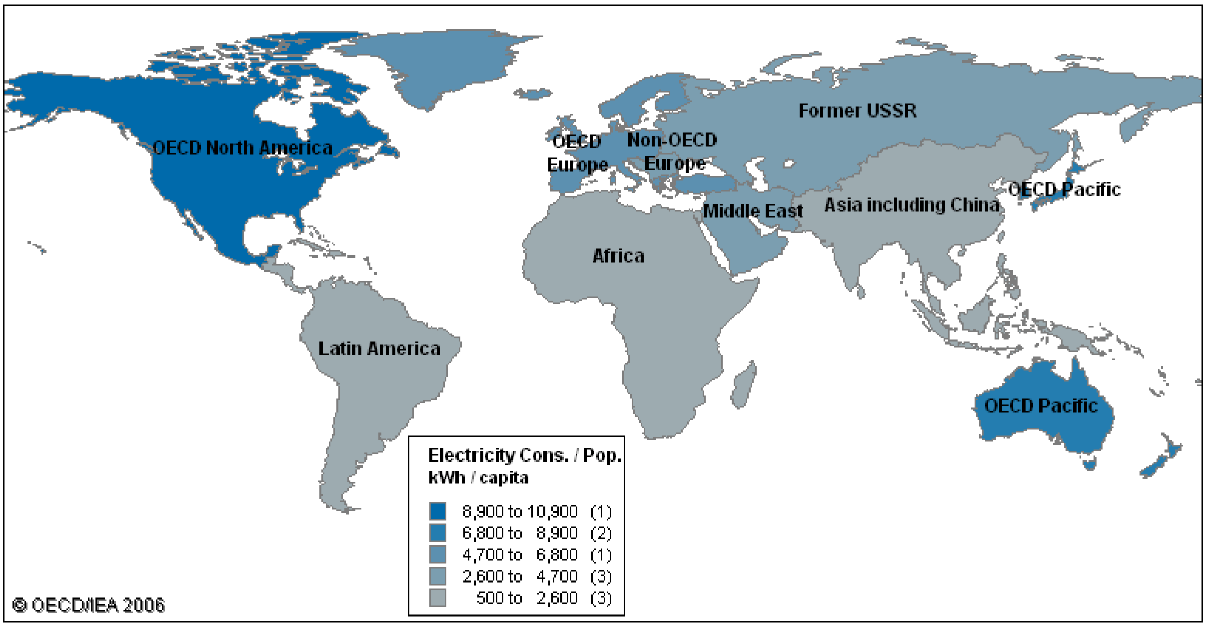
Figure 3.3

Internet users per 1000 people in 2007

Use data from http://www.internetworldstats.com/stats1.htm

Figure 3.4

Global electricity consumption



Source: http://www.iea.org/Textbase/country/maps/world/ele_pop.htm

Figure 3.5

Solar power in use at Patriensa, Ghana

Figure 3.6

Cellular mobile subscribers per 100 inhabitants, 2005

Source: ITU statistics (www.itu.int/ITU-D/icteye/indicators/indicators.aspx#, accessed 26 March 2007).