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ACTES DU COLLOQUE INTERNATIONAL SUR MATHEMATIQUES, SCIENCE ET SOCIETE

19 au 26 Janvier 2004

PORTO-NOVO, REPUBLIQUE DU BENIN

Open Source Overview and Opportunities

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What is Open Source?

Applications (Programs, executable files) and Texts which are

- Freely available online
- (In many cases) Encourage user contributions and innovations

Why Open Source is for Africa

Alternatives are unacceptable

Alternative 1: Buy commercial software

- Licenses and texts are expensive.
- Breeds dependency on expensive software.

Alternative 2: Copy

- Copying of software is stealing.
- Copying chokes invention. Inventions and innovations are the greatest generators of income. Any nation where intellectual property (copyright) is not respected can never become a first-tier nation.
- Software companies will eventually "tighten the noose" (Bill Gates on China)

Current Open Source Opportunities

Open Source Platforms

- GNU (www.gnu.org): Linux- or Hurd-based operating system

Open Source Applications or Tools

- StarOffice (Microsoft (c) Office clone, free for academic users): www.sun.com/products-n-solutions/edu/solutions/staroffice.html
- AbiWord (Microsoft (c) Word clone): www.abisource.com
- SciLab (Matlab (c) clone): www.scilab.org
- Octave (Matlab (c) clone): www.octave.org
- Ghostscript (Postscript and pdf viewer)
  ghostscript.com/doc/AFPL/get813.htm (Look for "Windows"section)
- DivX Player (www.divx.com)
- many, many others

Open Source Academics (Free online e-texts)

- Indexes of Mathematical Texts
  members.aol.com/johnp71/javasta3.html
  www.geocities.com/alex_stef/mylist.html
  spot.colorado.edu/~dubin/bookmarks/b/1240.html
- The Assayer
  www.theassayer.org/cgi-bin/asbrowsesubject.cgi
- University of Texas World Lecture Hall
  wnt.cc.utexas.edu/~wlh/index.cfm
- MIT Online Course Ware
  web.mit.edu/18.06/www/Video/video-fall-99.html
  ocw.mit.edu/index.html
- LON-CAPA (LearningOnline Network with a Computer Assisted Personalized Approach)

www.lon-capa.org
- Individual professors:
  Walter Wilcox (www3.baylor.edu/Physics/open_text/index.html)
- Online reference books
  Numerical Recipes (lib-www.lanl.gov/numerical/index.html)
- Online tutorials (academic or commercial)
  www.probability.net
  www.iec.org/online/tutorials/

Open Source Internet

- eGranary (U. Iowa -- On-site mirroring and satellite download enables high-speed internet over LAN)
  www.widernet.org/digitalLibrary

Conclusions:

- African academia should be actively involved in the development of open-source software, and in contributing to the availability of open-source texts.
- Africa should join the software development revolution. Software development is a fast road to income generation, with low capital cost. Expensive software tools may be circumvented if open source alternatives are actively developed.
- *Open Source is for Africa*

Inquiry Based Instruction Using Computers and Technology in Environmental Education

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Abstract:
This paper discusses educational initiatives for teaching environmental concepts, such as water quality, using inquiry-based learning through computer and other technologies in a cooperative setting. Biological and environmental phenomena often occur over long time periods in complex scenarios that cannot be easily reproduced in laboratories while field experiences may be impractical. Computer simulations may be uniquely suited for such complex environmental issues. Meanwhile, government, education, private and not for profit organizations have developed curricula and educational modules for a variety of environmental issues (often free), while private companies sell software and other products. The research is based on a survey of inquiry-based technology environmental modules, participation in the Middle School Teacher Quality Enhancement (MSTQE) program at Northeastern Illinois University (NEIU) and Global Education Initiative (GEI) after-school program; and the evaluation of environmental computer simulation modules developed at NEIU. The activities were evaluated for engaging students and meeting the learning objectives, as well as technical and operational criteria.

Many educators are conservative, avoid integrating computer use in classroom activities, and struggle to meet a broad base of government science objectives that are abstract with little relevance to students' lives. Most and especially older teachers fail to integrate computer use, complaining of lack of time, poor administrative support, low awareness of technology resources, fear of computers and dislike of computers. Recently the US education system has been taking a more constructivist inquiry-based holistic approach to teaching environmental studies, where students use research and technology to solve problems. Education programs are often available on-line through local, national and international government programs, schools and institutions. Activities may be structured or follow an open learning format in collaboration with other students and professional experts. Examples of these programs are provided at the SEED Science Center [http://www.seed.slb.com/en] (in French), US federal and state Environmental Protection Agency (EPA) [http://www.epa.gov/enviroed/], United States Geological Survey (USGS) [http://ga.water.usgs.gov/edu/characteristics.html], as well as through the NEIU's MSTQE and "No Child Left Behind" program focusing on at risk schools.

Both the IPLP/MSTQE and GEI programs promote the use of computer technologies through curriculum development in science education. The IPLP/MSTQE grant develops teacher-training programs to deepen the content knowledge of pre-service teachers, by bringing together faculty from specific content disciplines and faculty from the colleges of education to design new and pedagogically rich content courses. The program internalizes a greater depth, breadth and flexible repertoire of content and instructional methods to support student learning in public school classrooms. Technology and inquiry-based learning are cornerstones of the program, as are arts integration and adventure learning. Pre-service teacher are encouraged to see the interconnectedness and interdependence of knowledge to better assist their students in developing a coherent view of the world –and help them make sense of the science and math they are seeking to learn. The grants involves team teaching, a

learning communities model, interdisciplinary and thematic teaching, early guided sustained field experiences in schools, community and other relevant agencies, authentic use of technology integration, differentiated instruction for second language learners and special needs learners, culturally relevant pedagogy, and embedding of standards and collaboration with teachers in high need schools teaching in the 5-9th grades. In contrast, GEI is a global after-school pilot computer conferencing program that links youth around the world in learning science (e.g. water quality) designing and presenting results through business models.

Computer labs can provide college students an opportunity to study environmental issues through simulated role-playing or exploration exercises. Technology-based learning environments incorporating games into instruction have been found to improve students' skills in practical reasoning, complex problem solving, transfer of learning, and making inferences and engaging in inductive reasoning. In today's global culture computers and information technologies are ubiquitous in many schools; and students are comfortable with computer office skills, communication programs, Internet research, and interactive games. Furthermore, the use of computer simulations is uniquely suited for complex environmental issues.

Unfortunately, most commercial environmental CDs provide a narrow multi-media experience (text, audio and film clips) to a prescribed task list. However, there is a tremendous potential to modify and integrate educational CD's, Internet sites and other media to provide an interactive experience to study complex issues. Role-playing or simulations are especially appealing for ecology and environmental sciences because, 1) unlike physics and chemistry, it is difficult to obtain results in lab periods; 2) many phenomena are location and temporally specific, and hence inaccessible; and 3) modeling allows us to explore alternative outcomes for decision-making. In addition, environmental experts commonly use modeling to evaluate resources (e.g. groundwater and air quality), potential environmental impacts and proposed remedial actions.

Accordingly, simulation computer exercises were developed and later modified for undergrad students as as integrated part of environmental courses (Table 1). Students used scientific principals in solving applied environmental problems: identifying the questions, developing hypothesis, collecting and analyzing data to test the hypothesis, and explaining the results in a structured report format. Students work in small groups under supervision of the instructor to facilitate operations and enhance the learning experience in response to student questions and interests. The labs were administered with mixed results depending on technical difficulty, clarity of instructions and expectations, presence of the instructor, and student background and interests. Most students enjoyed the interactive and modeling programs, but were less enthusiastic about the research-based activities.

While the labs can offer a fun and effective learning experience, and many universities have appropriate facilities, the programs demanded a high level of technical expertise from the instructors or support persons. Instructions were minimal (commercial product) or complex (ALOHA use by environmental professionals) and require a good knowledge of the product in order to understand the product limitations. However, this also provides room for innovation. The initial experience points to the potential to develop evaluation criteria and identify suitable exercises for environmental (and other disciplines) courses.

Table 1: Sample Computer Environmental Exercises

Computer Programs Introduction to Environmental Studies/Science*	**Program Description and Media Source**
Great Lakes Explorer – Biodiversity	Commercial CD educational program Water Management Research Laboratory
Emergency Spill Laboratory (ALOHA)	Internet program modeling the impact of hazardous emergency spills, developed by US-EPA and available free.
Population Laboratory	Based on accessing multiple internet sites.
Prairie Studies	Based on accessing plant data and conducting analyses on the internet
Endangered Species Computer Laboratory	Based on accessing multiple internet sites, including web cameras and tracking bird migration routes.
Government Organizations Laboratory (World, US Federal and state EPA sites)	Based on accessing multiple internet sites cumulating in the students' local community.

Knowledge production, international information flows and intellectual property: an African perspective

Discussion paper prepared for the Association of African Universities DATAD Workshop on Intellectual Property, Governance, Dissemination and Funding Strategies, Accra, Ghana, February 19-20, 2004.

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Version 042e, edited by PJL 2004-02-28

Introduction

Until a few decades ago, or at least until the publication of the report of the International Commission for the Study of Communication Problems (1980) *Many voices one world*,[i] the information problem in Africa tended to be seen as one of supplying Africa, an "under-developed" continent, with information generated in the developed countries: sustaining a North-South information flow through aid and charitable enterprises in support of African development efforts. However, a balanced view requires that we also consider information flows in other directions, namely South-North and South-South information flows.[ii]

An important reason for considering South-North and South-South information flows is that we have realised that knowledge production is not the monopoly of the North. A growing awareness has developed of the wealth of Africa's knowledge base. Historical research, as reflected in UNESCO's eight volume *General history of Africa* (UNESCO 1981-1993) has shown that Africa's history is not anywhere near as dark and featureless as had been assumed. Centres of learning have been rediscovered, e.g. at Timbuktu, which rivalled their contemporaries in medieval Europe. We have been made aware of the contributions of ancient African thinkers and scholars[iii] to "classical antiquity" and "western science", or more correctly, to the shared knowledge of humankind. In recent years an appreciation has been developing of Africa's indigenous knowledge. It is no coincidence that this is happening at the same time that the African Renaissance, the New Partnership for Africa's Development (NEPAD), and the African Millennium are in the air, and that a new African Union has replaced the old Organization of African Unity.

Two responses can be observed to the rediscovery of Africa's knowledge wealth: One is to share it, proudly. The other is to keep it hidden, lest it be discovered and stolen or exploited by the North. This is an emotive issue. Word such as "piracy" and "looting" occur in the discourse. The threats are real, but we need to deal with them rationally and ethically. It is tempting to retaliate against hegemonic systems of knowledge production and dissemination by withholding our own treasures from the rest of humanity. But is it rational and ethical? Rationally, we need to consider whether we should we cut off our noses to spite our faces, isolating ourselves yet more from world knowledge production. Ethically, we need to consider whether Africa has a moral responsibility to contribute its knowledge to humanity.

How do we find the optimal balance between, on the one hand, protecting our knowledge assets, Africa's intellectual property, and, on the other, growing these assets and putting them to work for Africa's development and, ultimately, for the benefit of humankind?

Although this paper is concerned with intellectual property, it takes a moral, rather than a legal view. Its emphasis is on knowledge, which has different kinds of value in different contexts for different players. This creates a tension between the information commons and information as exclusive private property. The authors' concern, elaborated in the first section, is that the balance between the public good and private interests has been disturbed. Our premise, set out in the second section, is that there are general moral principles that can serve as a basis for decisions on North-South, South-North and South-South information flows. We take human rights and specifically information rights, and the concept of the common good as our point of departure and propose the four types of social justice (commutative, contributive, distributive and retributive justice) as the moral tool for charting a course between the extremes of the capitalist "free market" approach and that of knowledge as the common good of humankind.

In light of this the next three sections consider three directions of information flow (North-South, South-North, and South-South) from an African perspective. We first explore current developments in scholarly publishing and intellectual property rights (IPR) that affect the North-South information flow, and consider current responses, such as the open access movement, to the growing imbalance between rights holders and authors. These relations also affect South-North information flows, where both exploitation (of indigenous knowledge, for example) and neglect (of Africa's scholarly contributions to the world) need to be countered. Lastly, we consider the most neglected of the three, South-South information flows[iv] between African countries. The implications for the management of the intellectual property manifested in African theses and dissertations are then briefly discussed.

Knowledge: private greed, public good

There is a tendency to think of knowledge as an asset, or as a commodity. But knowledge does not behave like other commodities, such as land or mineral resources, which are finite. The person who imparts knowledge to others does not lose it. It remains the same whether it is known by one or by a million people. For example: the same knowledge embodied in a medical procedure or drug can save lives over and over again and (apart from cases of resistance to drugs by microbes) does not lose its value in terms of efficacy by being used repeatedly. However, its value to the knower in terms of marketable expertise may decline if it is widely disseminated. This shows that knowledge has different kinds of value.

(a) Instrumental value: This is the value found in the application of knowledge to improve the capacity of humankind to cope with its environment. This instrumental value of knowledge is illustrated in the way African people utilise environmental knowledge to survive and make decisions regarding the nutritional value of plants. Knowledge has this value when it is used in the interests of humankind, for the common good (e.g. the Salk vaccine against polio).
(b) Competitive value: Knowledge has competitive value by giving the knower a scarce resource that can be exploited to gain a livelihood, or some sort of competitive advantage. All knowledge tends to diffuse over time, albeit at different rates and in different spheres of society. But the competitive value lies in possessing knowledge

that others do not (yet) have. In order to treat knowledge as a commodity and subject it to the laws of supply and demand, scarcity has to be created or maintained artificially, through secrecy or other restrictions on its dissemination and use. This is very old. In the Old Testament (1 Samuel 13:19-21) we read that in the time of King Saul the Israelites were not able to make objects of iron since the Philistines held a monopoly on this technology. It is this value of knowledge that gives rise to the saying, "knowledge is power". The desire to prevent the diffusion of knowledge with competitive value, or at least to delay its diffusion, gave rise to various forms of IPR enshrined in law from the 18th century (Copyright 2004). This normally leads to asymmetric information markets where one information owner has more information that the other. This can give rise to market inefficiencies and the creation of monopolies. We can distinguish two aspects of competitive value: economic value and strategic value. Economic value is associated especially with knowing how and strategic value (e.g. market intelligence, military intelligence) with knowing that.

(c) Accumulative value: Although it is in the interest of the holders of certain categories of knowledge to keep it to themselves, knowledge is created cumulatively. Knowledge needed to create new knowledge. This gives rise to a third kind of value: the value of knowledge for the further development of science and scholarship. It is not in the interests of knowledge creators to impose a total blackout on what they know. To share and disseminate knowledge holds long-term benefits for them too. In a competitive environment holders of knowledge have to balance their short-term interests (which are served by maintaining their monopoly) and their long term interests (which are served by permitting the diffusion of their knowledge, so that it can be used in generating new knowledge). In our complex world, and given the complexity of our technology, few if any holders of knowledge are able to make scientific and scholarly progress without building on the contributions shared by others. But to ensure that such sharing takes place, all parties must be prepared to make contributions. Such sharing is to the benefit of the holders of knowledge not only because it enables them to proceed with the generation of new knowledge, but also because they, as members of society, benefit from any advantages that accrue to humankind as a whole, for example greater prosperity and well-being, more disposable income and more buoyant markets.

(d) Educational value: This refers to the value of knowledge for education, to equip successive generations of humans to improve the quality of their lives and the quality of their environment.

(e) Cultural value: This refers to the value of knowledge in strengthening the cohesion of communities and societies and enhancing the quality of communal life.

(f) Transcendent value: This relates to the value of knowledge in satisfying aesthetic, religious, spiritual or higher needs (those that are labelled as "self-actualisation needs" in the hierarchy of Maslow (1954). Here knowledge has value in enhancing the individual's or community's non-material quality of life.

Broadly speaking the six kinds of value listed here can be related as follows to the two categories of common/public and private good:

Common/public good	**Private good**
(a) Instrumental value	(b) Competitive value
(c) Accumulative value	
(d) Educational value	
(e) Cultural value	

(f) Transcendent value

Knowledge that is of value in service of the common good needs to be disseminated widely and without hindrance. Knowledge that is of value in service of the private good will be jealously guarded. The problem is that the same knowledge often has more than one type of value. The tension between the competitive value of knowledge and its other values is by no means new, but in our time this tension has been exacerbated by various factors.

For several centuries, starting with the Statute of Anne in England in 1710 (Copyright 2004) the North has had a system of intellectual property that sought to balance incentives for authors, inventors and creators of all kinds with the promotion of knowledge for the common good (Agha 1997). IPR were part of a balancing act between public good and private greed. This also applied to the production and dissemination of scientific knowledge. On the whole, scholars have conducted research and produced knowledge without direct regard for financial benefit, being primarily compensated by establishing priority of discovery, peer recognition, scientific prestige, academic tenure and the like. For that reason they desire that their contributions should be widely disseminated, with as few obstacles as possible. These desires largely coincide with those of their readers (Bronmo 1997).

Although copyright has been seen as a "bargain" between creators and the public, or authors and readers (Agha 1997), intellectual property is mainly owned by corporations, not by the authors, artists and composers who created the works (Hamelink 2000). The rights of creators have faded into the background and such financial rewards as there are, are reaped by the middlemen and disseminators. In the context of scholarly information, journal publishers are the most prominent group of middlemen.[v] To stay in business publishers must cover their costs and make a profit. Hence dissemination of scientific knowledge carries a price tag. Generally, based on the mutual understanding of the preservation of the information commons where the economic and the moral dimensions of information production and distribution are in balance, it has been assumed by both authors and readers that the price tag should not be such that it inhibits access. The publications should be affordable, if not by individual academics and students, then by libraries which can subscribe to journals and buy monographs in order to make them available to their clientele free of charge. Because more and more major publishers no longer share this commitment to the information commons, this is becoming more and more difficult. The institutions, such as the universities, which employ scholars are forced to pay many times over for the intellectual property generated by their own employees largely at the expense of the institutions and their governments. Typically a university has to pay:

- Page charges for the placement of articles in the journals
- Subscriptions to the journals for the university library
- For the photocopying licence to enable them to make copies for teaching purposes
- For clearance to include the same material in study packs (Consortium of University Research Libraries 2003)

The problem is compounded by the nature of the product. Each intellectual product is unique. If a researcher needs an article by Smith on topic X, an article by Smith on topic Y or an article by Jones on topic X will not do. Thus the publisher holds a *de facto* monopoly. The law of supply and demand does not work in such cases. That this is not mere speculation is demonstrated by the well-known phenomenon that the increase in journal prices has consistently outstripped inflation in the countries of origin. For example, in the USA the

Association of Research Libraries (ARL) reported in 2002 that serial prices had outstripped inflation for almost two decades (Kyrillidou & Young 2002); in the UK there was a 291% increase between 1986 and 2000, while the Retail Price Index in that country rose by approximately 75% (Consortium… 2003).

Thus, while a quasi-symbiotic relationship may have existed between authors, journal publishers and readers in the past, in recent times the relationship between journal publishers and authors/readers has become increasingly troubled. Today it seems that publishers on the one hand, and scientific authors and readers, on the other, inhabit two different spheres, each with its own value system: respectively that of free market capitalism and that of the common good. Until relatively recently these two spheres were in balance. More recently, since the early 1990s (Drahos 2003), the balance has been disturbed by a number of factors:

First, publishing has become big business globally. Gone are the days of gentlemanly scholar-publishers prepared to cross-subsidise loss-making titles in the public interest. Take-over upon take-over has occurred. It is difficult to keep track of who owns whom. The result is that many publishing houses belong to huge corporations with diverse business interests. In many cases these are multinationals. Their publishing holdings, sometimes acquired almost unintentionally as part of larger deals, may be minor compared with their other business. The bottom line for the publishing subsidiaries is profit or perish.

Second, the commodification of knowledge: a great deal has been written about the post-industrial society (Bell 1976), the information society (Naisbitt 1982, Webster 1995), the information economy (Freeman & Louça 2002), the knowledge society (Steward 1997) and the like. It may be that the change is not as revolutionary and the transition not as discontinuous as it has widely (and often wildly!) been depicted (Hamelink 2000). But there is widespread acceptance that information (or rather knowledge) is the dominant strategic resource of this new era, comparable to land in the agricultural era and to capital in the industrial era. This means that knowledge has commercial value, and gives rise to competition. Knowledge becomes a commodity (Lyotard 1984).

Third, the impact of digital technology: digital technology at first sight appears to be the answer to the cost spiral that characterises conventional publishing technologies, by reducing set-up costs as well as marginal costs. In this way it seems to make possible dissemination at close to zero cost. In practice this has not happened. The set-up costs of electronic publications do not differ much from those of printed publications. There may be some reduction in marginal costs, but the savings may be illusory as some cost elements (e.g. those relating to ICT infrastructure) are passed on from publishers to users (Summerfield 2004). However, digital technology also makes possible a much greater degree of control by publishers. Whereas publishers of print journals have very little control over who reads a given print journal issue once it has left their warehouses, publishers of electronic journals can use digital technology to monitor and limit access on a article-by-article basis. The monitoring of who reads what is in itself disturbing. Limiting access can artificially increase scarcity value. It is also in conflict with the values of authors, who are motivated to reach as wide a readership as possible. The possibility of charging clients a fee every time an article is downloaded has led to the realisation that out of print and backlist material still has commercial value. Not surprisingly we are seeing the focus of journal publishers shift from the journal as a unit, to the individual article as the sellable commodity.

A chemical equilibrium is a highly unstable state. So too is the balancing act described here. How do we respond if it is out of kilter? We believe that some moral guidelines may be useful. A brief excursus on a possible moral framework follows.

Moral principles: human rights and social justice

In a recent article (Britz & Lor 2003b) we have argued the need for a moral framework and a common vocabulary for dealing with the moral questions arising from phenomena observed in the South-North flow of information. Here we contend that this framework applies also to North-South and South-South information flows, i.e. to the flow of information between the countries and regions of the world generally. Three moral claims form the basis for this framework: They are that: (i) there are universal information related human rights; (ii) there is a common good that consist of those things that society shares to everyone's benefit; (iii) social justice is the primary tool that must provide the moral standard for assessing a society. These three moral claims are elaborated upon in that article. Here they are outlined briefly.

Universal human rights

Based on the moral theory of Rawls (1973) it is argued that social justice forms the basis for moral reasoning. However, a precondition for justice is the recognition that all human beings are fundamentally equal and free and have intrinsic human rights as well as the freedom to exercise them. Rawls (1973:60) formulates it as follows: "Each person is to have an equal right to the most extensive basic liberty with a similar liberty to others". Based on the assumption that information is a basic resource in any society that needs to survive and develop it can be argued, in line with Drahos (1996:155), that certain basic information rights (as an expression of Rawls's basic liberty) can be distinguished. These are:

- The right of freedom of expression and access to the information that is needed to exercise all other basic rights. The right of *access to information* is a positive right and correlates with the duty to share knowledge with others to enable them to exercise their basic rights (Britz 1998: 11). As such it is an expression of the moral principle of autonomy, which enables individuals to shape their own lives. The right of *freedom of expression* relates to both the negative and positive liberty of individuals and groups – the right not to be interfered with (negative) and the right to express opinions and receive information (positive).
- The right to communicate. This is a more recently developed right and implies the right of communities and nations to share their views and to learn from others. Hamelink correctly points out that we should move beyond 'information and knowledge societies' towards 'communication societies'. This right to communicate is essential in the globalise society in which we are living because "globalisation without dialogue becomes homogenisation and hegemony. Localization without dialogue becomes fragmentation and isolation" (Hamelink 2003).
- The right of individuals and groups to use and control information that they have generated themselves. The exclusive right to ownership of information, which forms the basis for IPR, is excluded as a basic natural right. It is rather viewed as a secondary economic-based right that can never override the right of access to essential information (Drahos 1996:14).

These rights are however *prima facie* and conditional and therefore not absolute. One can, for example, exercise these rights only insofar as they do not interfere with the rights of others.

Common good

Although human rights are seen as the basis for morality, the notion of a common good is also of vital importance for reflection on world information flows. It is concerned with certain values that are shared by a moral community. Shared values relevant to world information flows are the striving for mutual understanding, respect for one another (based on the acknowledgement of others' rights) as well as the creation of harmony. The common good can be maximised by the sharing of knowledge on an equal basis between the regions of the world, thereby creating mutual understanding. This implies that the gap between information rich and information poor, which is reinforced by the digital divide, is immoral.

Justice

Justice is the main normative tool that can be used to regulate world information flows. A fourfold typology of justice is put forward that can be used to ensure a fair and just South-North flow of information. In this typology, which is based on the United States National Conference of Catholic Bishops pastoral letter on social teachings of 1986 (republished in 1997), as expanded by Britz (1996), four interrelated types of justice are distinguished: commutative justice, distributive justice, contributive justice and retributive justice.

- Commutative justice requires "fundamental fairness in all agreements and exchanges between individuals or social groups" (National Conference of Catholic Bishops 1997: 42). Applied to the South-North flow of information it means amongst others that South-generated knowledge may not be taken and used without the consent and fair compensation of the South.
- Distributive justice takes as its starting point the fair and equal distribution of the resources that people need for their survival and well-being and implies that there should be some degree of equity in respect of material well-being, as in the right to health, sanitation, clean water and food security. In the context of information flows this implies the fair and equal distribution of information needed for survival and well-being as well as to enable mutual understanding. It is on the basis of distributive justice, for example, that the countries of the South have a moral claim to inexpensive generic anti-retroviral drugs to treat HIV-AIDS patients, and to investment in research on an anti-Malaria vaccine by the pharmaceutical companies of the North that have so far neglected this field because the commercial returns are not promising. However, this form of justice may allow the unequal distribution of certain categories of knowledge (Rawls 1973:64); for example knowledge that is protected under intellectual property regimes, such as trade secrets, with the proviso that such unequal distribution of knowledge is only justified if it is to the benefit of the common good.
- Contributive justice has a bearing on individual as well as social responsibilities. It implies that an individual has the responsibility to be active in society and to contribute in a positive manner to the achievement of the common good. Society has a duty to facilitate these individual activities without impairing the freedom and dignity of the individual. On the one hand, individuals have the responsibility to create knowledge that must benefit society. On the other hand society has the obligation and duty to ensure that the infrastructure is in place to provide individuals with the means to create and distribute knowledge and to ensure that they receive a fair economic return on their efforts. Applied

to the South-North flow of information it implies not only that African scholars have a duty to contribute their findings and insight to humanity generally, but also that the international systems of scholarly communication should be hospitable to their contributions.

- Retributive justice provides an enforcement component. It spells out clearly what constitutes non-conforming behaviour and provides for the fair punishment of those who have violated society's accepted principles of justice. In the context of North-South, South-North and South-South information flows it implies that legal mechanisms should be in place to protect the rights of knowledge producers, holders and users, covering not only the conventional intellectual property of North and South, but also the rights of traditional communities of the South in respect of their indigenous knowledge and cultural heritage resources. These include the moral rights of communities to be recognised as the creators of their cultural heritage, and the protection of this heritage against unilateral, insensitive and exploitative utilisation. This also implies the protection of the right to access their own knowledge, once produced and distributed in the marketplace.

North-South: Your money or your life

We have already pointed out that the balance between the capitalist and common good approaches to access to knowledge has been disturbed. The situation sketched above has been compounded by the effects of globalisation and particularly by international developments in respect of IPR. In the last decade there has been a strong trend towards stricter application of intellectual property legislation in the countries of the North. It has been accompanied by moves to extend the term of copyright (in the USA and the European Union), to develop a more restrictive copyright regime for digital media (under the slogan "digital is different") and to extend copyright to databases of public facts (Bollier 2003; Gross 2003). In so doing IPR owners are attempting to whittle away the "fair use" or "fair dealing" provisions that have long been applied to print media. The extension and stricter enforcement of IPR legislation have been motivated on the one hand by the desire to counter piracy and, on the other, by the realisation that intellectual property is a valuable asset, so that knowledge is seen as a commodity. The wealthy countries, in particular the European Union and the USA have taken the lead in setting international standards to ensure that IPR owners, which are mainly based in the North, receive worldwide protection (Britz *in progress*). Using their economic muscle and the small carrot and big stick approach to prising open the domestic markets of the less powerful countries, they have succeeded in linking IPR with general trade agreements and in establishing a framework for countries around the world to tighten their IPR regimes in accordance with these international agreements (Chang 2003).

The fundamental unfairness of the imposition of these regimes on the South has been voiced by Agha (1997:251)

> The arm-twisting imposition of intellectual property rights by developed countries on the developing ones, given their dominant position, is an unfair one. The irony of the situation is that developed countries have, by various means to the disadvantage of the developing countries, take out of those countries the genetic stock of fauna and flora for free, and to their immense benefit, on the assumption that such a resource is to be shared by the world. Should not knowledge and technology also be shared by the world on similar terms?

Two key instruments have been used to shift the balance in favour of IPR owners. The first is the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) of the World Trade Organisation (WTO). The second is the WIPO Copyright Treaty agreed in December 1996 at the Diplomatic Conference held in Geneva (World Intellectual Property Organization 1996; Harris 1997; Von Hielmcrone 2000; Thomas & Lee 2002). The international harmonisation of IPR laws and treaties is worrying because it places ever more power in the hands of large multinational IT and media corporations while steadily eroding the information commons (Britz *in progress*). Furthermore, it has been argued by Hamelink (2000) that the WTO's policies promote the concentration and consolidation of markets and the forming of oligopolies, which in developing countries leads to the ownership and dominance of media by foreign owners**.**

Well before these international moves for greater control of IPR and well before the advent of the Internet, scholars and students in the South suffered serious handicaps in keeping up with their counterparts in the North. In post-colonial times, they have been particularly hard hit by the steep increases in the price of material such as scientific journals. Given the unfavourable currency situation and low purchasing power of the South, these materials are in many cases unaffordable in academic and scientific institutions in the South, which have to make do with an ever-shrinking subset of core journals. One might have thought that modern ICTs would help to narrow the divide between information-rich and information poor, but this has not yet happened. Instead, we now have a digital divide, which is growing rather than narrowing (Arunachalam 2003).

> It is in the nature of any new technology to exacerbate the existing divide between the rich and the poor. The newer and the more potent the technology, the greater its ability to increase inequalities. The rapid changes taking place in the ways new information is published, stored, disseminated, and retrieved using the rapidly advancing information and communication technologies … have exacerbated the relative deprivation suffered by researchers in the developing world. (Arunachalam 2003:135).

Arunachalam points out how lack of access to electronic journals (due to financial constraints) makes simple tasks, such as following up references, that a researcher in the North can carry out with a few clicks of a mouse, a time-consuming activity that can take weeks to complete. Similarly lack of access to the Internet makes it very difficult for researchers in the South to participate in international research projects, to submit their papers to journals, or to take part in the refereeing and editing processes.

The effect of ICTs is not all negative, however. In a spirit of solidarity with scholars in the South, a number of schemes have been devised to assist them in gaining access to the scientific literature. An example is the Programme for the Enhancement of Research Information (PERI) of the International Network for the Availability of Scientific Publications (INASP). PERI comprises, among others a scheme whereby institutions in the poorer countries of Africa can gain access to current awareness services and online journals through country-wide access licences negotiated at very favourable prices (Programme for the Enhancement of Research Information 2001). There are various other schemes by publishers and journal aggregators to provide special deals and even gratis access for the poorest countries of the South, for example the African Virtual University and the Health Internetworking Access to Research Initiative (HINARI) (Arunachalam 2003).

A further encouraging development is the open access movement, including peer-reviewed open access journals, e-print repositories, and institutional repositories (Björk 2003; Consortium… 2003; Smith, et al. 2003; Tennant 2002). The movement encompasses a variety of initiatives by scholars, research libraries, research foundations, public interest institutions and various consortia and coalitions of these. This movement can be seen as a reaction and resistance to:

- restrictive IPR regimes
- the skewed relationship between publishers on the one hand and authors, their employing institutions and readers on the other
- the perceived predatory pricing and licensing strategies of certain major publishers, particularly in relation to the pricing of parallel print and electronic versions of journals
- continually rising subscription costs

The open access movement has received significant support from the Soros-funded Open Society Institute in Budapest, where a meeting was held in December 2001 to promote progress in international efforts to make research articles in all disciplines freely available on the Internet. A result of this meeting was the formulation of the Budapest Open Access Initiative, a "statement of principle, a statement of strategy, and a statement of commitment" (Budapest Open Access Initiative 2004). The statement recommends two complementary strategies, that of self-archiving (the deposit by scholars of their refereed journal articles in open electronic archives), and open access journals, which include new journals established on the open access principles and existing journals wanting to make the transition to open access. By February 2004, the statement had been signed by over 3400 scholars and by representatives of other role-players in scholarly communication (Budapest…2004).

The common thread in the various open access initiatives is to persuade scholars to make their research outputs available on the Internet free of charge (or at reduced or minimal cost) and with greatly relaxed copyright conditions. These movements are not necessarily opposed to IPR, but what they have in common is that they strive to open up space for the unhindered dissemination of knowledge generated by scholars for certain categories of use. One example is Creative Commons (2004), a web-based organisation that invites artists, photographers, musicians, educators and scholars who wish to make their work more readily available to others to post it on the Web under conditions that are less restrictive than the standard copyright conditions. Creative Common has designed a range of licences, under which authors inform readers, viewers or listeners that their work may be freely performed, copied or otherwise disseminated under one or more conditions such as the following:

- authorship is acknowledged
- the integrity of the work is respected
- the work is not used for money-making purposes
- the work is not adapted or incorporated in derivative works
- and various combinations of conditions

The upshot is that the authors retain copyright, but impose less restrictive conditions for the dissemination of their work, in order to make it accessible to a larger audience.

The Public Library of Science (PLoS) is an initiative by scholars. It is a non-profit organisation of scientists and physicians who are "committed to making the world's scientific and medical literature a public resource". The organisation's goals are to:

- "Open the doors to the world's library of scientific knowledge by giving any scientist, physician, patient, or student – anywhere in the world – unlimited access to the latest scientific research.
- Facilitate research, informed medical practice, and education by making it possible to freely search the full text of every published article to locate specific ideas, methods, experimental results, and observations.
- Enable scientists, librarians, publishers and entrepreneurs to develop innovative ways to explore and use the world's treasury of scientific ideas and discoveries." (Public Library of Science 2004)

PLoS aims to publish peer-reviewed journals of high quality, using a new business model that will enable PLoS to make all the published work available online immediately, free of charge and without restrictions on re-use. Essentially, the journals will be financed by the imposition of a modest charge per article published. This is to be paid by the authors or their sponsoring organisation. The charge will be reduced or waived in the case of authors (such as those from the South) who cannot afford to pay. The initial issue of its first journal, *PLoS biology*, was published in October 2003; *PLoS Medicine* was to follow shortly thereafter (Public… 2004). The PLoS web site, at http://www.plos.org/about/index.html, is worth visiting, since it also provides a definition of open access and background on the open access movement.

Other examples are the International Scholarly Communications Alliance (ISCA), the Scholarly Publishing and Academic Resources Coalition (SPARC) and BioMed Central (Arunachalam 2003; Consortium… 2003. From the point of view of North-South information flows, these initiatives provide scholars and students in the South with free or relatively affordable access to the world's scientific and scholarly literature. At the same time, the initiatives also open up new possibilities for the South-North and South-South flow of information.

South-North: does charity begin at home?

It seems hardly necessary to state that African societies, communities and scholars have much to contribute to a humane world. By a humane world we mean a world in which cultural diversity and different modes of imagining and knowing are not merely tolerated, but appreciated and encouraged. Their suppression in order that all knowledge and understanding can be fitted into the straitjacket of a dominant western world-view is also an impoverishment of the wealthy nations. These nations should be as concerned about the disappearance of indigenous knowledge, arts and culture and languages spoken by small groups of people, as they are about the reduction of biodiversity. Western governments and pressure groups campaign for the preservation of tropical rain forests and other biomes in the South, inter alia to combat the loss of biodiversity. But comparable efforts are not made to prevent the extinction of languages and cultures that are bearers of unique knowledge.

Over the centuries Africa has been exploited in various ways, including the wholesale plundering of Africa's human resources in the slave trade and the exploitation by colonialists of Africa's mineral resources, genetic diversity, and cultural treasures. Today the exploitation of Africa's indigenous knowledge[vi] has come to the foreground. This knowledge, the product of millennia during which African communities came to terms with and adapted to their often harsh environment, was initially disregarded as unscientific folklore. Today, bio-prospectors

are visiting rural communities, making friends with the "locals", questioning them about their use of plants in traditional medicine, and taking samples back to the North where the active constituents are isolated in the laboratory and then patented.

An example: The San (Bushmen) in the Kalahari know of a succulent plant (*Hoodia gordonia*) that relieves hunger pangs and allows them to carry on during a hunting expedition even when they have had nothing to eat for some time. The South African CSIR identified the active constituent of *Hoodia* and was in the process of patenting it and making a deal with two foreign pharmaceutical companies, Phytopharm (UK) and Pfizer (US), to develop an appetite suppressant prescription drug. This was done without informing or consulting the San. The Working Group of Indigenous Minorities in Southern Africa (WIMSA), a San-owned regional networking organisation learned of this in 2001 and alerted the San. The South African San Council was then appointed to negotiate with the CSIR. When the story appeared in the media, public pressure helped to force the CSIR to negotiate with the San. Ultimately an agreement was reached in terms of which the San will receive a modest share of royalties on sales of the drug (Geingos & Ngakaeaja 2002; Wynberg 2003).

It is easy to respond to this type of situation with righteous indignation. Among the emotional responses to biopiracy and the misappropriation of African indigenous knowledge for selfish commercial purposes may be a defensive approach: to shroud it, as far as possible, in secrecy, so that it cannot be misappropriated and exploited by the North. This is not entirely irrational, since indigenous knowledge has ritual and spiritual dimensions and is imbedded in its cultural and religious context. To share this knowledge with others who do not share the context and ethos of the community that created the indigenous knowledge, entails risk (cf. Nakata 2002). In addition to the risk of commercial exploitation, there is a risk that the knowledge may be dealt with out of context in an insensitive and disrespectful manner. One thinks of the popular depictions of traditional healers as "witch-doctors", or of the way the Maori *haka* has been trivialised by New Zealand rugby teams.

But righteous indignation is not a very constructive attitude. Secrecy is not the best way to deal with indigenous knowledge. Knowledge has a tendency to spontaneous diffusion. Things that are hidden invite investigation by the curious. Scarcity adds to the market value of information, so that those entrusted with the secret may be led into the temptation to reveal it by the offer of financial reward. If the secret is discovered accidentally, it will be all the more difficult for the originating community to patent or copyright it. These are pragmatic arguments. There is also a moral argument, based on the principle of contributive justice, referred to earlier. If the secret remains hidden, how can other communities in the country of origin benefit? Contributive justice entails that, in the interest of humanity, communities and nations should be prepared to share their knowledge with the rest of the world.

"Sharing" indigenous knowledge is not a simple matter. There are significant problems in recording indigenous knowledge and processing it so that it can be retrieved using global information systems (Meyer 2003). But these problems are technical. To speak of the "globalisation" of indigenous knowledge begs more difficult moral questions, such as:

- Who may gain access to the recorded indigenous knowledge?
- Does the community that originated it have any say in who gains access?
- May indigenous knowledge be exploited for commercial gain?
- Does the community that originated it have any say in the exploitation of the knowledge?

- Does the community that originated it have a right to compensation, or to a share of the profits?

Similar questions arise in respect of other forms of knowledge or information that is exported to the North, such as digitised collections of African heritage materials (Britz & Lor 2003a) and the export of African heritage materials such as rare books, writers' archives, traditional artefacts and works of art, etc. (Britz & Lor 2003b). Means must be found to protect African intellectual property, while at the same time contributing it to humanity. These means could include national legislation specifically protecting indigenous knowledge, the inclusion of indigenous knowledge in legal deposit legislation (Lor 2002) the use of model contracts binding on bioprospectors and others wishing to record indigenous knowledge, and the utilisation of various components of the international intellectual property regime (copyright, patents, trade secrets, trade marks, etc.), adapted as necessary for the special characteristics of indigenous knowledge (Lipinski & Britz 2001). Such measures are preferable to protectiveness and secrecy, which will tend to ghettoise Africa's achievements. Africa should share its knowledge resources with the world, judiciously and proudly.

Africa's knowledge resources include research contributions by African scholars. Here the problem has not been to prevent the dissemination (whether acknowledged or not) of African knowledge resources to the North, but rather to promote dissemination and specifically to cross the significant barriers that impede South-North information flow. Apart from the difficulties that scholars of the South face in gaining access to information resources from the North, there are barriers of disinterest and prejudice to be faced:

> Inadequate access to literature or information is not the only problem faced by scientists in developing countries. An equally important problem is that research conducted in developing countries lacks visibility. Nobody notices it. Nobody quotes it. It gets buried in an obscure corner of the world output of literature. (Arunachalam 2003:137)

African authors who wish to publish locally face the problem that there are not many African scholarly journals of good quality, and the number is declining. Many are poorly run and edited and appear irregularly, so that libraries in the North do not want to subscribe to them (Rosenberg 2002). Omekwu (2003:132) states that journal publication in Africa is "highly unsustainable". The journals lack a steady subscriber base and are financially insecure. Marketing is minimal and distribution is poor. Many lack a consistent supply of articles (Omekwu 2003), possibly because of a tendency of authors to seek publication in more prestigious titles published in the North (Britz & Lor 2003b).

If an African scholar does succeed in having his/her work published in a national or regional (African) journal, it may simply be ignored (Gibbs 1995; Britz & Lor 2003b). Readers in the North may simply dismiss articles from the South as not worth reading, or if they seek to read them, they may find it difficult to gain access to the journal in which it is published.

As stated earlier, the principle of contributive justice implies on the one hand that African researchers and scholars have a duty to contribute their findings and insight to humanity generally, and on the other, that the international systems of scientific and scholarly communication should accept their contributions. Internationally, interest in this problem has grown in the last decades, and a number of schemes can be mentioned that make it easier for

African scholars to make their contribution to the world (Arunachalam 2003; Britz & Lor 2003b).

One of these is African Journals On-Line (AJOL), a project of INASP. This scheme initially made the tables of contents of 15 English-language scientific journals published in Africa available on-line and provided a fee-based article delivery service. It has in the mean time been expanded to make over sixty titles, including French-language and South African journals available on the Internet (International Network for the Availability of Scientific Publications 2004). Other initiatives aimed at making African journals more readily available world-wide using the Internet include the African e-Journals Project (AEJP) of the African Studies Centre at Michigan State University (African e-Journals Project 2004) and the inclusion of a number of African biomedical journals in the Bioline full text service (Bioline International 2004; Rosenberg 2002).

Hope is not only offered by these initiatives, which aim specifically to improve the North's awareness of and access to the knowledge production of the South. The open access initiatives referred to in the previous section also facilitate the dissemination of knowledge created in the South. Given adequate computer workstations, Internet connectivity and sufficient bandwidth, African scholars can also submit their articles for refereeing and publication in open-access electronic journals such as those of PLoS. As was pointed out, the business model of initiatives of this kind relies on a contribution from the authors or their institutions for each article published electronically, but it has also been indicated that such charges will be reduced or waived in cases where the authors or their institutions cannot afford this. African scholars can also post their refereed articles on appropriate e-print archives. African universities can establish functional digital institutional repositories at a fraction of the cost of maintaining a conventional university press. Some universities in South Africa have already embarked on this; no doubt this is also happening elsewhere in Africa. To the extent that search engines are unbiased (which is not to be taken for granted) the WWW is unbiased in providing access to sites regardless of where they are located.

Discussing the various modalities of dissemination, Arunachalam (2003: 138-143) makes a number of recommendations to authors of the South:

- Scientists everywhere, and especially in developing countries, should make every effort to publish their work in, and give their full support to, those journals that have adopted the [open access] policy proposed in the open letter [to publishers, circulated by scientists].
- Scientists from developing countries should submit their work to SPARC journals rather than to the expensive journals they are trying to replace. [SPARC encourages editorial boards of excessively expensive journals to start competing journals of high quality that can be published at much lower cost.]
- Developing country scientists should use the existing [open full-text or e-print] archives to disseminate their work as well as to learn about the work of others. They may also establish institutional archives and national e-print servers, especially in fields such as agriculture and health sciences…
- Scientists from developing countries should encourage all journals to join … efforts [such as PubMed Central, a digital archive of life sciences journal literature].

Scholars are both producers and consumers of knowledge. Arunachalam reminds us that in our capacity as producers of knowledge, we need to take into account the needs of its consumers. For every article a scholar writes, many more are first read. Scholars also have a

responsibility to the institutions that employ them, to select publishers and publishing modalities that are in the long-term interest of their institutions, for example by selecting publishers that allow them to make multiple copies of their own articles for educational use.

South-South: do good fences make good neighbours?

It is often overlooked that the South-North flow of information is critical to the South-South flow. This is because much of the knowledge produced in the South is published in the North, and because discipline-wide bibliographic control is also largely based in the North. Since bibliographic control is poorly developed in the countries of the South, we have to rely on bibliographic databases produced in the North. Similarly, resource-sharing systems such as interlending schemes are poorly developed in African countries. In many cases it is much faster and more certain for an African library to obtain a copy of an article that was written or published in a neighbouring country from the British Library at Boston Spa than from the capital of that country.

Ideally African countries should reduce their dependence on the information infrastructure of their former colonial rulers by improving national bibliographic control and developing regional resource-sharing schemes. This is unlikely to happen soon. In most African countries national bibliographic control leaves much to be desired. Often legal deposit legislation is out of date and largely ignored by publishers. The national publishing and bookselling industry may be poorly organised. National bibliographic agencies frequently lack the resources to operate national bibliographic services on an on-going basis (Omekwu 2003). If the production of scholarly literature is not recorded, it becomes almost impossible to identify and locate existing information resources in response to information needs. Even knowledge produced in one's own country is inaccessible.

The prospects for regional resource-sharing schemes are poor if, at the national level, there are few resources to share, and few resources to operate resource-sharing systems. It comes as no surprise that interlending is poorly developed in many African countries. Ironically, resource sharing seems to flourish most in well-resourced countries. An ethos of sharing is difficult to cultivate when there is little to share. Unreliable transportation and telecommunications infrastructures also inhibit resource sharing.

All is not gloom, however. During the past decade there has been a significant improvement in Internet connectivity. As more material is being published electronically (born-digital), as more print and other analogue material is digitised, and as more band-width is made available, some of the barriers to resource-sharing fall away. Prospects are best, at least initially, for sector-specific resource-sharing systems of limited scope, such as DATAD, which covers a clearly defined and relatively homogeneous category of material.

The political environment is also more favourable today than it has been in the past. Will the library and information sector be able to hitch a ride on the African Renaissance bandwagon? To support NEPAD? To be recognised as a portfolio of the African Union? Our track record in generating enthusiasm at government level is not good. Yet the terms "renaissance", "partnership" and "African century" all evoke concepts that favour an awareness and appreciation of Africa's knowledge resources and the continent-wide sharing of knowledge. There is a challenge to our profession to seize the opportunity.

Application to theses and dissertations

In the introduction to this paper we promised to consider the implications of general moral principles for the electronic storage and dissemination of theses and dissertations. The following are some issues and guidelines:

Commutative justice requires fundamental fairness in agreements and exchanges between parties.

With respect to South-North information flows, South-generated knowledge as set forth in theses and dissertations may not be appropriated by the North without the consent and fair compensation of the South. This is an issue of IPR, which may be complicated by a number of factors. Two questions arise: whose intellectual property is it, and has it any commercial value?

Who is the holder of the intellectual property? The author as creator of the knowledge is the natural holder. However, in the case of a thesis or dissertation, the student may be required by the university to sign away his/her copyright. It may be argued that this is a fair exchange: the university provides tuition, guidance and infrastructure, which enable the student to produce a report and ultimately to receive a degree. In exchange for this, it may be argued that the university should hold the copyright. However, in light of the principle of commutative justice, we need to consider whether the power relationship between the university and the student is such that the student can freely enter into such an agreement. If the university holds a monopoly on degrees and if the student, at the outset, is not aware of what he/she is signing away upon enrolment, this may be construed as unfair. A further factor to take into account is the extent to which the student had to pay for the services provided by the university. Of course, in many cases tuition costs are heavily subsidised by the state.

A complicating factor arises in post-graduate research when the student makes use of informants and information from local communities. Can the student or the university in fairness claim IPR over a report that relies heavily on indigenous knowledge or even on data collected with the cooperation of a given non-traditional community? Commutative justice requires that the researcher may not take advantage of the ignorance or lack of sophistication of such a community. Prior consent must be obtained and fair compensation must be made for the community's contribution. Depending on the nature of the contribution made by the community, compensation might take the form of a simple debriefing or feedback session, a community problem-solving workshop, assistance with a community development project related to the topic of the study, the development of a commercial undertaking that will provide an income for community members, or royalties on the sales of a product developed on the basis of information that the community provided. The compensation should be fairly negotiated. A serious lack in the current IPR regime is that it does not make provision for the acknowledgement and, by implication, fair compensation of communal IPR. This has led to the exploitation of the communally owned knowledge of indigenous peoples.

Commutative justice also requires that the issue of who owns the resulting IPR should be agreed up-front with the student, with all the cards on the table. Furthermore, it can be argued that the student should be afforded an opportunity to participate in any enterprise that may arise from the research work, and share in any profits from it. In relation to DATAD specifically, the requirement is that students should be informed at the outset that their theses

and dissertations will be added to an electronic database, and will be made available for use. The student has the right to know what kinds of use will be permitted and what categories of users will be allowed access.

Distributive justice is concerned with the fair and equal distribution of resources needed for survival and well-being. If the research leads to the development of improved agricultural practices, health care, sanitation, building methods etc., this implies that the knowledge that was gained should be shared: with the community where the research was carried out, with other communities in the country, with other countries in the South, and with the North, depending on the scope and impact of the research, and on the nature of the needs that the results can address. This moral obligation is an expression of the right to communicate, which has been identified as one of the basic preconditions for social justice. Certain knowledge may be protected under intellectual property regimes, giving rise to unequal distribution. This can be justified if it is in the general interest. For example, the research may lead to the granting of a patent to the university. The university stands to receive royalties that will enable it to provide a higher standard of education and enhance its research capacity for the benefit of the country. This has to be weighed up against the common good. The answer would differ depending on how critical the benefits are and on the size of the group affected. For example, one would expect different decisions in respect of a chemical substance that ensures whiter teeth compared with one that can be used to treat a life-threatening disease.

Contributive justice implies that both the university and the student have an obligation to be active in society and contribute to the common good. This has implications for the nature of the research undertaken. Further, there is a moral obligation to disseminate any knowledge that may benefit society. Universities should require their research students to include plans for the dissemination of research results as part of their research proposals, and should ensure that these plans are carried out before the degree is awarded. The universities themselves should have public education and communication programmes in place to ensure that research results are disseminated for the common good. (This does not preclude measures taken to ensure a fair economic return, in so far as this is compatible with the requirements of commutative and distributive justice.) Furthermore, the universities have an obligation to provide appropriate long-term access to the theses and dissertations of their students, which implies a responsibility for their long-term preservation.

This also applies to the South-North flow of information. Universities in the South cannot refuse to contribute their knowledge to humanity as a whole (again, subject to fair compensation as appropriate). On the other hand scholarly institutions in the North have a responsibility to provide mechanisms for the efficient dissemination and fair evaluation of theses and dissertations from the South. This includes providing feedback in the form of peer evaluation of African research outputs and devoting time to serving as external examiners of African students. This will enable the universities of the South to measures themselves against other institutions. Concomitantly, bibliographic control agencies in the North (such as abstracting and indexing services) have a responsibility to include bibliographic entries and abstracts for African theses and dissertations in their databases, so that they can be retrieved and accessed by the world-wide scholarly community.

Retributive justice is concerned with sanctions taken in response to inappropriate behaviour. This could be inappropriate behaviour on the part of the student, (such as plagiarism, dishonesty in respect of research data or improper exploitation of research participants), thesis

supervisors (for example passing off students' work as their own), and others who have access to the thesis or dissertation. In the context of global information flows, inappropriate behaviour could include failure to respect IPR (copyright, patents, designs, etc.) arising from the research. The international bodies concerned with IPR should exhibit the same alacrity in dealing with violations of the IPR of the South as they exhibit when the multinational corporations of the North complain about "piracy" and the like. Too strict and one-sided application and interpretation of IPR are also unfair behaviour. Measures should be in place to protect the common good as well as the basic liberty of individuals and communities in those cases where the application of IPR is unjust.

Conclusion

Towards the end of his paper, "Ethics and copyright: a developing country perspective", Agha (1997:256) writes:

> The basis of globalisation is interdependence. Interdependence calls for sharing, understanding and tolerance. Knowledge is a tool for human development and progress. The imposition of barriers to access and use [of] knowledge is detrimental to human society. Information is similar to the air we breathe. It should be free. If one sector of society is disadvantaged and poor then ethically it is incumbent on the richer sector of society to respond with generosity and care. Likewise in a global society in this age of globalisation. Inequities between peoples in this interdependent world if allowed to persist will eventually prove to be a greater burden for the richer sector of society.

This is an impassioned and idealistic statement. It largely reflects the principles of social justice as derived from the US National Conference of Catholic Bishops. Social justice provides a useful tool to evaluate the fairness of our current international systems of scholarly communication. It is clear that social justice is not adequately reflected in the international economic and political relations that impact on scholarly communication. However, that should not stop us from imagining and developing systems that *are* fair.

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Learning in a Digital World: The Role of Technology as a Catalyst for Change

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Wherever we go in the world today, we find the new technologies: mobile phones, computers, and cybercafés. Two weeks ago my husband and I were in the ancient city of Timbuktu, Mali, on the edge of the vast Sahara desert. We rode camels for two hours north into the desert to a Tuareg encampment. While we were having tea in the plain, simple tent of our host, no modern amenities anywhere in sight, I heard a phone ring. The young son in the family reached among the sticks supporting the top of the tent and grabbed a satellite phone. Later I sat in a cybercafé in Timbuktu among young Malians checking their e-mail and noticed that even the landscape of the ancient city was dotted with TV antennas, satellite dishes, and a mobile phone tower.

The emergence of new technologies is changing society, changing the way we live, the way we communicate and do business—and also the way we learn. Our educational systems are facing significant pressure to change in order to adequately prepare students to live, learn, and work in a global, digital age. As a result of this pressure, computers are being introduced in many schools around the world to enhance teaching and learning and prepare students for the new world in which they live.

Three examples
In Ghana, for example, senior secondary schools are partnering with local computer businesses to set up computer laboratories. The business provides refurbished computers, installs the software, recruits and trains a teacher, develops the curriculum, and maintains the equipment. The school collects a fee from the parents for each child each term.

In Botswana, the Ministry of Education has partnered with a British NGO to set up computer laboratories in selected secondary schools. Classroom teachers are recruited to become computer teachers and provided with training.

In my home state of Ohio in the USA, the government has funded, over a period of several years, the SchoolNet initiative that provides five computers in every primary classroom, Internet access in every school, professional development for every teacher, statewide software licensing agreements, and equity grants for low-wealth districts.
The philosophy of the Ohio SchoolNet initiative, based on the standards of the International Society for Technology in Education, is that:

- Technology is a tool for learning
- Technology should be integrated across the curriculum
- Computers belong in classrooms rather than laboratories
- Classrooms should be connected to the Web
- Teacher training should focus on curriculum integration as well as on skills

Why ICT in schools?
A decade ago, Hawkridge identified four basic rationales why schools are using computers:

- The *social rationale* proposes that computers are part of society and thus students need to understand how they work and what they can and cannot do.
- The *vocational rationale* says that learning to use computers is important because it enhances employment opportunities.
- The *pedagogic rationale* presumes that computers can improve teaching and learning, while
- The *catalytic rationale* supposes computers as catalysts to enable desired change to take place in schools.

Technology as a catalyst for change

While all four rationales are valid and relevant, I'd like to focus our attention on the catalytic rationale. My thesis is that technology can be a powerful catalyst for change in schools. A growing body of research literature, including my own work with teachers in middle school classrooms, supports this thesis. Learners learn best when they are actively engaged in their learning. And technology has the potential to engage learners in challenging, open-ended activities in which they have control over the pace and direction of their learning. When learners have access to the rich resources on the Internet and can communicate with others via e-mail, they become more independent in their learning. Teachers who use technology in the classroom find that their role shifts from being "the sage on the stage" to being "the guide on the side," and the classroom environment becomes less teacher-directed and more learner-centered.

Education in the USA and other countries is undergoing a major paradigm shift (change) from traditional learning environments focused on the teacher as the "deliverer" of knowledge to new open learning environments focused on the learner as information seeker.

Although the movement in the USA took root first at the primary and secondary levels of education, it has had an impact on tertiary education as well.

In this session, I will discuss the limitations of traditional learning environments, describe the new learning environments, and argue that technology can be a catalyst for educational change. Finally, I will demonstrate examples of classroom activities that use technology as a tool to support project-based learning.

Limitations of traditional learning environments

Why do we need a change? What are some of the limitations of traditional learning environments in which, for the most part, the teacher talks and the students listen and write?

1. Schools today are expected to meet the diverse needs of many learners. In the past, schools served a smaller and more select group of students. Classes were more homogeneous. Now schools are struggling to accommodate increasing numbers of learners, who have a wider range of backgrounds and needs. Schools must be responsive to their special needs; not all learn at the same rate in the same way.
2. The school curriculum has become compartmentalized into distinct disciplines (mathematics, science, language arts, social studies, art, music) that do not reflect the interconnectedness of human knowledge. Schools need to encourage learners to take a broad view and follow links among concepts and ideas across disciplines. Problem solving in the real world requires the ability to see a problem from multiple points of view.
3. Traditional schooling primarily relies on words—written and oral—as a means of communication and learning. Most people, when they hear the word "information,"

form a mental image of text. But information today is multimedia, that is, it comes in multiple forms of media. We are surrounded with images, sounds, movies, beeps, music, videogames, animations, live drama, dance—all of which are ways of communicating information. If we limit learners to a text-based environment, it is like putting blinders on them. Schools should encourage learning through a variety of media in order to accommodate different learning styles and preferences.

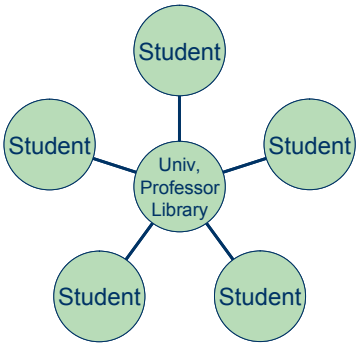
4. Learning is not limited to schools. Learning occurs everywhere in our interactions with other people and with our environment. It is inherently a social activity. Schools can no longer rely on teachers as the main source of knowledge. They need to forge connections with the local community and with the world at large, and allow learners mobility to move back and forth within the larger community.
5. The school curriculum has become centralized in an effort to ensure that all learners attain certain minimal standards. But in many schools, the minimum has become the maximum. Learners are not pushed to go beyond the requirements, to explore ideas or topics that spark their interest. Teachers need flexibility in designing curriculum that is relevant to learners' interests, takes advantage of local needs and resources, and encourages learners to reach their full potential.
6. Assessment is typically unidimensional. Schools rely on written tests that cannot assess the full range of one's achievements. Traditional tests focus on low-level cognition—facts, knowledge, and skills taken out of context—rather than analysis, synthesis, critical thinking, and problem solving, which are more highly valued in today's information society.

In response to these acknowledged limitations of schools, education is undergoing a major paradigm shift from traditional learning environments focused on the teacher as the "deliverer" of knowledge to new open learning environments focused on the learner as information seeker. The following chart describes that shift.

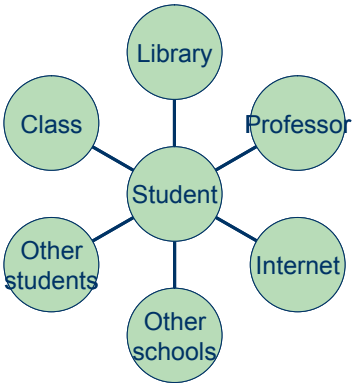
Traditional Learning Environments		**New Learning Environments**
Teacher-centered instruction	→	Learner-centered instruction
Passive learning	→	Active learning
One primary media	→	Multimedia
Progression through one path	→	Progression through multiple paths
Individual work	→	Collaborative work
Information delivery	→	Information exchange
Focus on facts and knowledge	→	Critical thinking and problem solving
Isolated, artificial context	→	Authentic, real-world context
Assessment by testing	→	Authentic assessment

(Authentic = relevant to the real world, meaningful.)

The traditional learning environment is teacher-centered:



The new learning environment is learner-centered:



The roles of the teacher and learner change in the new learning environment.

The teacher becomes a:

- facilitator
- coach
- guide
- co-learner

The learner becomes a:

- information seeker
- explorer
- problem solver
- co-teacher

Assessment in the new learning environments has an authentic context

- Performance assessment
- Portfolio assessment
- Project-based assessment
- Observation

Assessment may be

- Teacher assessment – teacher assesses learner's work
- Peer assessment – learners assess each other's work
- Self-assessmemt – learner assesses his/her own work

What are the characteristics of active, learner-centered learning? (Grabinger & Dunlap, 2000)

- Learners take responsibility and initiative for their own learning
- Learners develop self-reflection and metacognitive skills
- Learners engage in generative learning activities

- Learning experiences are authentic, relevant, meaningful
- Assessment requires learners to apply their knowledge in context
- Learners have meaningful interactions with peers, teacher and others

What is the role of technology in this new learning environment?

- Technology becomes a tool for active learning
    - productivity tool
    - communication tool
    - research tool
    - problem-solving tool
- The Web gives learners direct access to a huge library of information
- The Web is hypermedia, not linear
- The Web is multimedia, not just text
- Learners can be authors and problem solvers, not just audience
- Educational software encourages problem solving and critical thinking

Similarly, there are two models of online education

- Teacher-centered
    - Delivery of information to learners
- Learner-centered
    - Exchange of information among learners/teacher
    - Learners seek own information from Web, books, other people
    - Example: MBA Without Boundaries programme at Ohio University

Two examples from Ghana

I have written elsewhere about my research in middle school classrooms in the USA (see references), but now I'd like to share two recent examples from Ghana, one I just learned about on the Internet and one from my personal experience.

Young people and teachers in a rural village in Ghana were given the opportunity to create an account of their lives using digital video, which was turned into a website and film as a medium for cultural exchange. The experience of seeing their local knowledge valued by and shared with the global community on the Internet appeared to act as a catalyst for community action in the village. A primary factor contributing to the success of the project was that the people's experience of ICT was active rather than passive. In addition, the active creation of digital media enabled them to develop some ICT skills and literacy. The researchers, who were also studying the problems of rural schools, concluded that "even limited access to ICTs might be used as a lever to more interactive yet culturally appropriate pedagogy."

The second example is my experience teaching Multimedia and Web Authoring to third-year education students in Ghana this past term. I'm used to teaching hands-on in a computer lab, one student per computer, maximum of 25 students. But in Ghana I faced 88 students in a lecture hall for three hours, followed by "practicals" in the lab: two sessions of 44 students with two students per computer. The Internet crawled at a snail's pace, when it worked, and sometimes the power went off, forcing us to cancel the rest of the lab. Nevertheless, the students were eager to learn and not deterred by the challenges. And I was determined to model for my students how to establish a project-based learning environment despite the large class size and limited facilities. There was no way I could help everyone in the crowded lab, so I asked them to help each other. Everyone was a teacher as well as a learner, even me. By

the end of the term, they had all completed three multimedia projects, including a personal web page. Their pride in their projects was obvious.

One of the students told me afterwards how much he appreciated the project-based approach:

> Sometimes I'm sitting at the computer and I just open up my PowerPoint project or my web page and say to myself, "I did that!" In our other courses, we are expected to listen to lectures, write what the lecturer says, and remember it for the exam. One time I was interested in a topic. I did some extra research in the library and even went to an Internet cafe. But when I included that information on the exam, it was marked wrong. We should be encouraged to learn on our own, to go beyond the lecture, but instead the educational system discourages initiative.

Conclusion

Technology can be a powerful tool for learning. Computer and information technologies encourage the development of problem solving, analytical, and research skills and enable us to communicate with each other wherever we live. Furthermore, it can be a catalyst in changing the learning environment from one that is teacher-centered (teacher talks, students listen and write) to one that is learner-centered (teacher and learners are co-learners). In a technology-rich open environment, learners are actively involved in seeking and analyzing information, exploring and sharing new ideas, encountering and solving problems as they work at their own pace on interdisciplinary projects that are meaningful to them. Of course, technology if and of itself does not automatically result in these benefits. But by using technology in creative and innovative ways, we open up opportunities for learners to reach their potential as problem solvers and critical thinkers.

Examples of project-based multimedia learning activities

- Forest animals of Ohio - PowerPoint
- Festivals of China - HyperStudio
- Greek philosophers' newsletter - Publisher
- Children's story book - Publisher
- Math lessons for Ghana schools - PowerPoint

Examples of problem solving software

- Concert Tour Entrepreneur – simulation of running a business as a band agent
- Africa Inspirer – problem solving while learning geography of Africa
- Great Ocean Rescue – science problem solving about oceans and environment
- Oregon Trail – social studies simulation of westward expansion in 1800's in USA
- Where in the World is Carmen San Diego? – problem solving and logical thinking

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Current and Future Opportunities in Wireless Communications

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Abstract

Wireless communications has significant advantages over conventional wire-line communications, including ease of installation, adaptability, and flexibility. For this reason, many developing countries are strongly promoting the development of wireless communications. This presentation will give an overview of current and future opportunities in wireless communication, including different cellular telephone technologies (GSM, GPRS, and EDGE, 1x CDMA, cdma2000, UMTS, TD-SCDMA, Smart Antenna) and wireless LAN (Local Area Network). The presentation will describe both technical and business aspects of the different technologies

.

Personal Communications Overview:

There are many alternative systems of electronic communication. Decision-makers must be well-informed as to the advantages and disadvantages of each system, in order to make intelligent choices as to which is most appropriate for a particular area or application. Hence, we begin this presentation with a top-level overview of communications alternatives.

Note that this paper is concerned with *personal* (one-to-one) communication rather than *broadcasting* (one to many), which is an entirely different topic.

Wired Communications

We first consider wired communication, which is the benchmark against which other systems should be evaluated. In the modern world, "wired"means optical fiber, which has far more capacity than old-fashioned copper wire at very low cost. China is a good example of the optical fiber revolution. China and the U.S. Were recently linked by optical fiber, resulting in immediate, drastic improvements in service. It is now possible to call China from the U.S. for about 6 cents per minute, with comparable or superior voice quality to calls within the U.S. Internally, China has installed an optical "backbone" which has proved more than able to keep up with the huge increase in telephone use.

Of course, wired communication has its drawbacks as well as advantages. Installation can be a problem, particularly in congested urban areas or difficult terrain. And once the system is installed, it is fixed, and cannot be changed in response to different usage patterns. Finally, the wired user is immobilized – he/she must go to a particular place to make or receive a call, and cannot move from that place until the call is finished. It is this last consideration particularly which drives the development of wireless technology.

Wireless Terminology:

Before launching into our discussion of wireless alternatives, we first present a brief introduction to some important concepts and terminology used in wireless communication. A wireless system consists of a number of users with telephones (which are called "mobile

stations"), who communicate with a fixed tower which recieves/transmits signals to all of the mobile users (which is called the "base station"). A connection which has been established between a mobile station and the base station (enabling the transmission of information) is called a "link". The connection from mobile station to base station is called the "uplink", while the connection from base station to mobile station is called the "downlink".

The actual signals which are transmitted and received by the base station and mobile stations are electromagnetic waves which have a characteristic frequency. There are many types of wireless signals already transmitted (i.e. Television, two-way radio, police and military communications), and in order to avoid interference the different signals are assigned to different ranges of frequencies. A range of frequencies is called a *frequency band:* hence each type of signal is assigned to its own frequency band.

Naturally, the mobile stations and base station must have an agreed-upon system of communication. The signal frequency and format must be exactly specified and scrupulously observed in order for communication to take place. Such a specification is called a *standard*. Standards are typically developed together by the large communications companies (such as Motorola, Ericsson, Nokia, etc.) who manufacture telecommunications equipment. Standards are developed through a series of committee meetings, and may take several years to work out, as each company tries to influence the standard to its own advantage.

Wireless Options

Wireless option 1: WLAN (Wireless Local Area Network)

The simplest and cheapest wireless alternative is called Wireless Local Area Network.. Here coverage is restricted to a "hot spot", a local area such as home, office building, hotel lobby, or airport waiting room: the user loses contact if he/she strays from the coverage area. There are two leading standards for WLAN, namely 802.11 (also known as "WiFi") and "Bluetooth". Of the two, Bluetooth is especially suited for shorter-range, smaller devices. In recent years, WiFi "hotspots" have proliferated in restaurants, hotels, airports, and other public spaces.

Wireless option 2: WLL (Wireless Local Loop)

Wireless Local Loop is similar to WLAN, but on a larger scale. One of the main challenges in telecommunications is the "last mile problem", namely how to reach multiple users in a concentrated neighborhood. WLL has emerged as a solution which is cost-competitive with wired solutions. Many Third-World countries who are "telecommunicating" for the first time are turning to WLL.

Wireless option 2: Cellular

Cellular systems represent the next step up from WLL. Users are no longer restricted to a single coverage area. Instead, a network of base stations is constructed, where each base station provides coverage for its own "cell". here is a "handoff" protocol between base stations which enables continuous transmission when the user moves from one cell to another. Current base stations are designed to reliably serve users with speeds up to 250 km/h. However, the added mobility comes at a price. Compared with the two previous options, cellular systems are considerably more complex and costly to build and maintain. The average number of paying subscribers per base station must be high in order to offset the costs

of the system. But notwithstanding these problems, cellular systems have exhibited explosive growth, as is evident on the streets of most large cities throughout the world.

Wireless option 3: Satellite

The final wireless option we consider is satellite communications, which is able to provide universal world-wide coverage. The promise of a truly global system is unfortunately more than offest by practical and economic difficulties. Satellite systems are far, far more expensive to set up and troubleshoot when problems arise. They require that users carry around large, cumbersome handsets. Furthermore, users must be outdoors in order for the weak signal to reach the satellite. A satellite system called "Iridium" designed and constructed by Motorola was technically a success but still went bankrupt because of lack of customers. Only a few people with highly specialized needs were willing to pay a premium for the service.

Summary of options

In summary, It is clear that each of the communications options presented above has its own niche. Applications in which wired communication has a clear advantage include network backbone and semi-rural situations. WLAN is best for highly local applications such as home or office. Wireless cellular is the preferred choice for urban and suburban users, which is the dominant user population worldwide. Satellite is best for emergency or temporary coverage, as well as coverage in ultra-remote regions.

In view of these conclusions, this talk will focus on wireless cellular, which promises to be the high-volume mobile communications option of choice in the forseeable future.

Wireless Cellular Alternatives

Within the realm of wireless cellular, there are a number of alternative technologies to choose from, which we will discuss below.

Analog:

The original technology, known as "Analog" is very similar to 2-way radio, except that it uses a different frequency to avoid interference. Analog is disappearing worldwide in favor of digital, for reasons which will be given below. The switchover period from analog to digital requires dual-mode phones, which can switch between analog and digital mode depending on the type of local coverage.

Digital (general):

In digital telecommunication, the voice or data information to be transmitted is first encoded as 0's and 1's before transmission. This digitization enables a number of advantages, as follows.

First, the digital information may be *compressed* before transmission. Voice coding is similar to the familiar with JPEG or MPEG technology, which greatly reduces the size of picture or movie files on the computer. A low-quality sampled voice signal (such as analog transmits) requires 64 kilobits per second; modern CELP (Code Excited Linear Predictive) voice coders can reduce this down to less than 5 kilobits per second, a tenfold reduction in information which translates to a tenfold increase in capacity.

Second, the simplicity of digital signals enables far greater flexibility in transmission. Different data streams may be *multiplexed* into a single signal. In addition, the signal no longer need be assigned to a single frequency, but may be spread over a band or bands of frequencies. In this way, more efficient use is made of the spectrum, which is the precious resource which limits system capacity.

Third, *error correction coding* may be employed to increase the fidelity of the signal. Digital bits are rearranged ("interleaved") or reprocessed (via convolutional or turbo coding) so that receiver errors can be detected and corrected. This is especially important in data transmission, where error rates must be reduced to well below one in a billion.

These three advantages give digital technology an unbeatable advantage over analog. Digital is without question the better technology. Analog will eventually disappear.

Digital alternatives: Time Division and Code Division Multiple Access (TDMA and CDMA)

Within the realm of commercially available digital wireless, there are two broad classes of technologies, namely Time Division Multiple Access (abbr. TDMA) and Code Division Multiple Access (abbr. CDMA). The difference between the two is related to how multiple users are accommodated, as we shall explain below.

TDMA:

In TDMA, the different users take turns sending their messages. The system divides time into 'slots', allocates different slots to different users. Some time slots are allocated to downlink (station to mobile), and others to uplink (mobile to station). The predominant TDMA technology available today is GSM, which is by far the leading digital technology in the world today, with over 250 million subscribers worldwide in the year 2000 (and far, far more today).

CDMA:

In CDMA, on the other hand, all users' signals are transmitted at all times, but are distinguished by distinct "codes"or signature patterns. For current CDMA, downlink and uplink use separate frequency bands. The leading CDMA technology today is IS-95 or narrowband CDMA, which was developed principally by the American company QualComm, and implemented primarily in Korea and the U.S.. CDMA enables more efficient use of the spectrum and promises higher capacity (on paper, at least!) , but is somewhat more complicated than TDMA. TDMA is the more established and mature technology, but CDMA is gaining market share.

Geography:

The prevalence of the different digital technologies is highly dependent on geography. In Europe, GSM is hugely dominant (which is natural, considering that GSM originated there). In the U.S., there is a mixture between GSM, IS-136 (another TDMA standard), and CDMA. Japan (which as far as commercial deployment may be the most advanced wireless nation in the world today) is also mixed, but appears to be moving more towards CDMA. China (which is a leading player on the cellular wireless stage, as well as the largest market in the world) is

currently GSM, but moving quickly towards CDMA and a home-grown hybrid technology known as TD-SCDMA which we will discuss later.

As far as Africa is concerned, GSM is dominant due to Europe's heavy influence. In 2002, there were over 20 million GSM users in Africa, with heaviest concentrations in South Africa (9.5 million), Morocco (4 million) and Egypt (3 million). In contrast, in 2002 there were only about 2 million CDMA subscribers in all of Africa, and only a handful of countries (Angola, Congo, Egypt, Nigeria, and Zambia) offered CDMA service in selected metropolitan areas. The total of 23 million subscribers in December 2002 was up 135% over the previous December: and the forecast for the end of 2003 was 38 million cellular users in Africa, with about 95% GSM.

Suppliers:

The leading companies involved in the design and manufacture of cellular equipment include Qualcomm (CDMA), Motorola, Nokia, Ericsson, Siemens, HuaWei (China). Smaller companies are also entering into cell-phone manufacture, particularly in China. However, the base station equipment production is limited to the giant companies, due to the extremely high development costs.

Future Prospects for Cellular:

General:

There are an increasing number of wireless applications which require higher and higher data rates, and consequently larger and larger amounts of information transfer. These applications include: Camera or video phones; Internet-enabled MP3 players with mobile music download; Internet commerce; retrieval of medical records; etc. These new applications require systems with higher capacity, and specifically systems which are designed to handle general digitized information and not just voice data.

The migration towards general digital data (not just voice data) also entails a difference in how the data is transmitted. Over the internet, for instance, data is transmitted in *packets* rather than a continuous, ordered stream. The order in which the packets are received is not important, so long as the receiver can reconstruct the order and reassemble the data once it has all been received. This method has the advantage that channels can be *shared*, i.e., whenever a user is not using his/her channel then the channel may be used by another user.

In the wireless world, analog systems are known as “1G” (“First generation”). Current TDMA and CDMA systems are characterized as “2G” (“Second generation”) . Now wireless developers are working hard on “3G” systems designed specially to accommodate data transmission. An overview of the “3G”scene in TDMA and CDMA is given below.

3G TDMA:

The GSM standard even now has a commercially-available enhancement called GPRS (General Packet Radio Service) which is designed for the transmission of packet data. In addition, higher data rates are accommodated by EDGE (Enhanced Data for Global Evolution), which increases capacity by changing the way data is transmitted (more bits are transmitted at once).

3G CDMA:

The IS-95 CDMA standard also has an enhanced version called cdma2000, which may be implemented in stages. The first stage (called 1x) achieves data rates up to 384 kilobits per second while using the same frequency band. This speed is roughly equivalent to an internet connect via cable modem. The second stage uses a frequency band which is roughly three times wider, and can reach data transmission speeds of up 2 Mbps.

As we indicated previously, the U.S. company QualComm has been the dominating influence in the development of IS-95 CDMA, and cdma2000 as well. In an attempt to break this dominance (and to avoid paying royalties to QualComm, several European and Japanese companies have banded together to come up with an alternative standard to cdma2000 called W-CDMA, or Wideband CDMA.

Newer technologies

In this section we indicate some additional innovations in the area of wireless cellular, which are either enhancements (multiple antennas) or alternatives(TD-SCDMA and OFDM) to both TDMA and CDMA.

Multiple antennas: Multiple antennas may be used to transmit and receive lower-power signals while maintaining high signal quality. Since each user's power may be lowered, the system capacity may be significantly raised. Although antennas may be added at both the base station and the mobile station, development so far has focused on adding antennas at the base station. One such innovation is called Smart Antennas, which is a technology via which individual signals to/from the base station may be individually steered specifically towards the appropriate mobile station. Conceptually, this may be compared to the use of a megaphones to direct sounds towards particular locations, or to turning towards a sound in order to hear better. This makes it possible to transmit more signals with less interference, which translates to greater system efficiency and capacity.

TD-SCDMA: TD-SCDMA(Time Division-Synchronous CDMA) is a new technology which originates from China. It is a hybrid which combines good features from both TDMA and CDMA. One of its appealing features is load balancing: it can dynamically shift resources (i.e. bandwidth) between uplink and downlink so that no resources are wasted. In addition, TD-SCDMA receivers utilize"joint detection" to estimate all signals at once, rather than extracting them one by one as is the case in other technologies. This serves to reduce interference and increase signal quality. If technical difficulties are overcome, this may become the technology of choice for the wireless data revolution.

4G (OFDM): Several companies (including Motorola) are already considering "4G"systems which will enable wireless video. One candidate for 4G technology is Orthogonal Frequency Division Multiplexing (OFDM), which spreads the signal over several frequency bands. Commercial availability of such systems is probably more than five years in the future.

Summary

Electronic communications is an inexpensive, convenient, efficient way to decrease the load on transportation infrastructure. For example, a conference like this one could be conducted over the internet via NetMeeting for a tiny fraction of the cost, and with far less trouble. Increasingly, commerce and social interaction will be conducted long-distance, and an increasing share of this communication will be wireless. Higher bandwidth technologies mean more communication options (pictures, internet) and increase the utility of wireless technology.

Knowledge is power, in industry and commerce as well as education -- and good communication provides knowledge in a timely and convenient fashion. Dependable, high-

capacity long-distance communications should be a top priority in developing nations who are vying to enter the same economic arena as the U.S., Europe, and Japan. These nations must recognize the key role of wireless communication, and make intelligent choices in order to enter the highway to economic success.

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