

Technology, Education, and the Information Highway

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Abstract— Advancing technology will fundamentally change our world. Education will be key to ensuring that these changes are positive. As information highways are intrinsic to both, this paper provides some insight into how they might evolve.

I. TECHNOLOGY WILL MAKE A DIFFERENCE¹

Over the next fifty years, the world's population should stabilize around fifteen billion. Either the forty million new jobs needed to maintain full employment are created each year or the underdeveloped to developed population ratio will increase by a factor of five. Tomorrow's world will be shaped by the interplay between these demographics and three areas of technology: communications, biotechnology, and robotics. Whereas in the past, demographic effects were offset by dispersal of the benefits of technological advancement, current intellectual property protection makes this much less likely.

While telecommunication and information technologies are being used to counter pressures of global competition in the fast-paced information intensive developed world (and economies and businesses are being restructured in the process), their application to the international financial community may diminish the value of the nation-state. As the trillion dollars per day in electronic transfers exceeds the GNP of most countries, the multinational corporations controlling these transfers may have more impact on local economies than their governments.

Advances in biotechnology are beginning to move agricultural production from land to factory-based operations and advanced robotics are beginning to decrease the need for low skilled labour. Removing the value of the two primary resources available to the world's underdeveloped nations, the nations in which most of the population growth will occur, will have significant repercussions. In this dichotomy between the positive and negative impacts of technology on the developed and underdeveloped nations (respectively), some balance will be attained. Education will be key to both evaluating the appropriate trade-offs and ensuring that the balance achieved is a positive one.

At a more personal level, competition amongst the forty million people for the new employment opportunities that are created will be intense and education will be a key differentiator.

II. EDUCATION HAS A PROBLEM

*In the same time that the world's population increased fifty times, the available information increased by a factor of ten million. "That's not a man trying to catch a Ferrari, that is a snail trying to catch a space ship."*² With the knowledge base doubling nearly every seven years,³ students who learned $x\%$ of the knowledge base at the turn of the century now learn some $6/1000$ ths of a percentage of x . Alternatively, half of what first year science oriented baccalaureate students learn is obsolete by the time they graduate. This not only stresses curriculum and the skill requirements of the teaching staff, it fuels the need for lifelong learning and underlies the increased responsibility that the corporate world is taking toward education.

I have heard it said that more teachers need to retire so that the young, technology literate ones can teach our children more relevant skills. I was recently a guest at a talk by Daniel Burrus, author of *Technotrends*.⁵ According to him, despite the fact that laser surgery is superior in virtually all respects to conventional methods, only 4% of the surgeons in the US will perform it. If you had the option of being operated on by a new graduate out looking for his first live human or by a greying experienced surgeon who had invested the time to master the new techniques, whom would you choose? If technology and education are just for the young and the restless, we are in serious trouble!

If this explosion in knowledge is to be kept tractable, we will have to begin using technology to teach as opposed to just teaching technology. The former is, of course, a far more difficult problem and one that you are much more familiar with than I. A recent review of the problem set, and the associated Canadian work in progress, can be found in the recently accepted Network Centres of Excellence proposal on Telelearning from Simon Fraser University.⁴

III. THE FUTURE IS KNOWN⁵

The future should not be a scary place -- after all, some of it you can visit and much of it you can see coming. Relativity aside, you can walk through time: you can travel back more than a hundred years by visiting parts of Nepal or a thousand years by visiting the Irian Jaya. Conversely, trips to parts of Hong Kong and Japan will take you forward some five to ten years.

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Technology developments take time -- on average, at least ten years from idea to full deployment. Hence, all the technologies that have the potential to affect us over the coming decade, already exist. Yes, there are problems -- big changes usually result from synergistic developments across a number of fields and most successful technologies are rarely used as initially intended -- but they are here and they are known. Why not make use of them now?

IV. TIME IS NOT CONSTANT⁶

In terms of technological progress, within a given frame of reference, time is not progressing at a uniform rate -- it is accelerating. Whereas it took some twenty years to evolve from the mainframes of the sixties to personal computers, the same aggregate amount of progress now takes less than five. A year's worth of progress today will take six months a year or two from now. In essence, progress is feeding on itself and this acceleration will not end any time soon.

Time is becoming the currency of the nineties.

V. MULTIMEDIA

As a result of the well-documented progress being made in the electronics industry, the costs of capable electronic componentry are decreasing exponentially. As a result, the conversion of all media types to digital formats is becoming economical. The media transparency that results from this conversion leads to the integration opportunities referred to as multimedia -- see Fig. 1. With the ability to easily transpose and combine content between media, the formerly separate printing/publishing, video/motion picture, and information services industries are beginning to merge and grow. Development of multimedia content is expensive, however, and material developed will require wide distribution for it to be economically attractive.

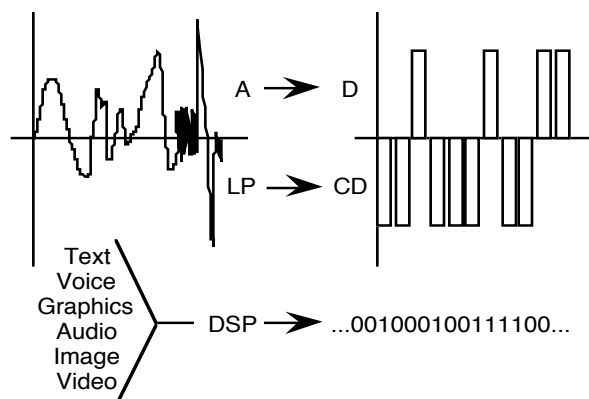


Figure 1. Advances in digital signal processing make it economical to convert all signals to digital form.

Using numbers from the Alberta Government's 1994 roundtable document, there are some 534 000 students in twelve grades in Alberta. There are 1000 hours in a school

year and six subjects are covered. Let us say that we were to develop a multimedia mathematics course with a useful life of five years and that one-half the Grade 12 students would take it. If we spent 500 hours of development time to produce each hour of multimedia material and paid the developers \$100k/person-year of effort, the bill would come to \$4.3M. Alberta-wide this comes to \$38/student. Using the rule of tens, Canada-wide, the cost is \$3.80/student and, if the course were accepted across the US, the cost would be 38¢ each. With common curriculum, you might end up competing with Hollywood!

VI. THE INFORMATION HIGHWAY IS HERE

Victor Schnee has pointed out that the 'information highway' is more akin to the opening of a public beach on the ocean of information than it is to any highway currently in existence.¹⁰ Nonetheless, the information highway is the accepted term, and is the term that is used in what follows.

For the past few years the titans of media and communications have waged a war for the digital future. // Shambling towards their distant goal of a wired world, they have been too busy to notice the unruly bunch of computer hackers, engineers and students scurrying about at their feet. They should have paid more attention. For while the giants have just been talking about an information superhighway, the ants have actually been building one: the Internet. // Last year the Internet as a whole doubled in size, as it has done every year since 1988. It now reaches nearly 5m 'host' computers, each of which may connect several individual users [see Fig. 2]. At the same time the Web grew almost 20-fold; in just 18 months users created more than 3m multimedia pages of information, entertainment and advertising. No one knows how many people are behind this, but an estimate by John Quarterman, an Internet analyst, put the number of users at 13.5m in October 1994. Whatever the number is today--20m is not an unreasonable guess--it will be at least half as big again a year from now. No communications medium or consumer electronics technology has ever grown as quickly; not the fax machine, not even the PC. At this rate, within two years the citizens of cyberspace will outnumber all but the largest nations.⁷

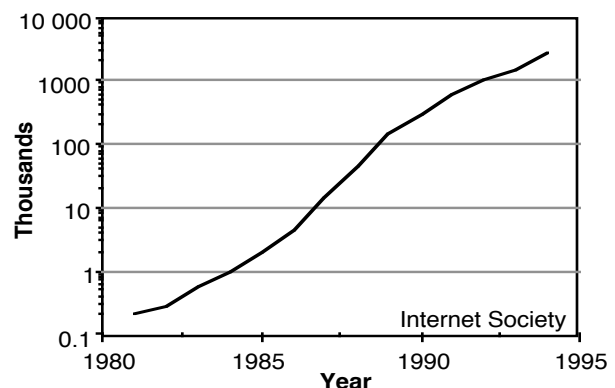


Figure 2. Growth in host computers on the Internet.

But how will the currently bandwidth-limited Internet evolve? With the developing media independence, the requirements for separate voice, data, and video transport systems are decreasing and convergence between the telecommunication, computer, and cable television networks is becoming advantageous from both a customer and a service perspective. According to the network report card appearing in Table 1, such a converged network should utilize the network management capabilities of the telephone companies, the broader bandwidth access infrastructure of the cable companies, and the information content available on the Internet.

Table 1
Network Report Card⁸

	Telephone	Cable	Internet
Availability	A+	B+	B
Affordable	A	B-	C+
Ease of use	A+	A+	C-
Security	B-	F	C-
Billing	A+	B	D+
Information	D	C-	A+
Openness	B-	D	A
Bandwidth	D	A-	D

Since this solution is unfortunately unlikely, there are a number of developments underway to permit each network player to provide another's services via their own infrastructure.⁹ The most noteworthy current example concerns the cable companies' announcements with respect to commercial deployment of cable modem technology. Using upgraded cable infrastructure, these devices will be capable of providing bi-directional data services in the 10 Mb/s range.

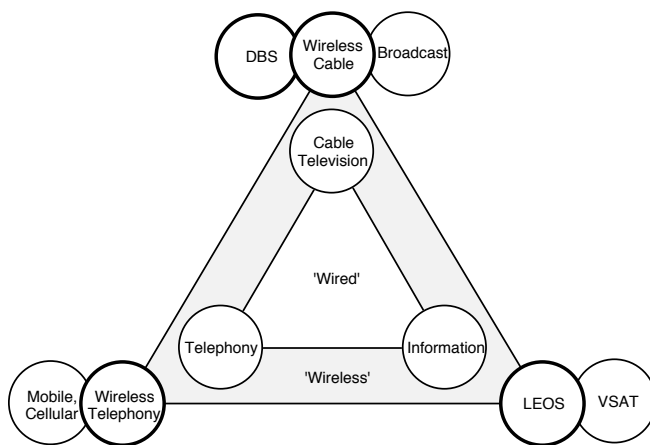


Figure 3. The expanded playing field.

With the phenomenal progress in electronics also making possible wireless alternatives to the current cabled networks, it is also becoming possible for each player to economically bypass the others' infrastructure completely. This new playing field is shown in Fig. 3. Telephone companies wishing to provide less expensive wider bandwidth data services in residential areas, for example, might deploy

wireless overlay systems operating at frequencies near 30 GHz. Low earth orbit satellite systems may provide similar capabilities on a global scale.

*"Who will dominate the new information era, telephone carriers or cable companies?" a reporter for a national magazine was asked. Asking which of these two will dominate the new information era, he responded, was like asking "whether Cunard Steamship or Union Pacific would dominate the aviation age."*¹⁰ The real threat to both industries will come from outside.

Accepting that there are a number of significant players with a vested interest in evolving current information highway infrastructure, as well as a number of avenues available to them, let us look briefly at what the highway might carry. Bypassing the obvious 'multimedia' answer, one wonders about voice and video. After all, the Internet is world-wide and multimedia does include audio and video, right? Boy, avoiding long distance charges would be nice!

Regardless of the underlying infrastructure used to support the information highway, there is a significant difference between the voice and video traffic carried on current telecommunication and cable television networks and the data traffic carried on the Internet. The difference has to do with the time sensitivity of the data streams. Whereas Internet is a store-and-forward network, voice and video networks operate in real-time. Store-and-forward networks sequentially forward and store the data in multiple computers enroute from the source of the data to its destination. Intermediary computers only forward received transmissions when they have time. Receiving pieces of a phone call, a few bits at a time and with varying delays between the bits, does not do much for a caller's patience. In real-time networks, the data streams are continuous and this does not happen.

While transmitting voice and video over the Internet is currently possible, the quality is poor and the required computer equipment at each end rather prohibitive. Bandwidth on the Internet is increasing, though, computer costs are coming down, and work is underway to provide more real-time services. Telcos and CATV companies, beware!

VII. DISTANCE BECOMES IRRELEVANT

Though currently held back by the capability of the associated opto-electronic equipment, the capacity of a single mode fibre optic cable is effectively unlimited (~75 000 GHz). Commercially available systems currently run at 2.5 Gb/s and lab-based systems are some 40 000 times more capable. As these developments are deployed, the incremental costs of higher bandwidth long distance traffic will, as shown in Fig. 4, approach zero. The repercussions are significant. First, current tariff structures are backwards in that long distance tariffs are disproportionately high while local access rates are disproportionately low.

Second, the associated economies of scale imply that the player that aggregates the most traffic will have a cost base below that of all other players. In essence, the regulatory

structure is backwards as it is the long distance markets that should have been regulated, not the access ones (where there are no such economies of scale and for which multiple independent infrastructures are being developed).

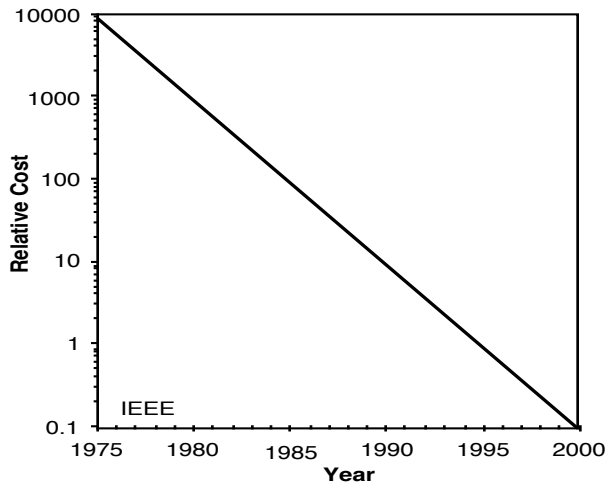


Figure 4. The decreasing cost of long distance transmission¹¹.

Lastly, if long distance tariffs become marginalized, many of the value-added applications related services could be provided through off-shore facilities. This will also open the door to third world 'white collar' telecommuters, possibly teachers teleconferencing to their students from abroad. Virtual universities already exist.

VIII. THE NETWORK IS THE COMPUTER

In contrast to the computer industry, which is adding video and audio capabilities to their intrinsically intelligent digital machines, the video gaming industry typified by Nintendo and Sega is adding significant computational and graphics capabilities via their machines to intrinsically dumb analog television sets. In terms of processing capability, the latter route is significantly more cost effective. For the price at which one could add a CD-ROM to a PC, one could obtain a 3DO 'video game' machine with a built in CD-ROM, a processor faster than many workstations, a high speed video animation capability, and ports for the keyboard/memory additions needed to give 'computer' capabilities to their television set. In one US trial, the 3DO machine was incorporated into the converter box supplied by the cable television company. If one wants the information highway to deliver material to the home, maybe it should be compatible with a 'game' machine. Or maybe not...

While Internet may provide the networking infrastructure, and advancing electronic and fibre optic technologies cost effective terminals and distance insensitive networking capabilities, the software interoperability/compatibility problem remains. A key to the Internet explosion in the early nineties was a program put out by Netscape (formerly Mosaic) Communications. Other than providing a greatly simplified user interface, the key to Netscape was that, for the first time,

it laid out -- from the top or network side down -- a hypertext markup language (html). Anyone wanting to make documents available at a web site, regardless of their home terminal's capabilities or operating system, simply used html to define their document. Conversely, anyone wishing to view or print the document, simply needed to have an html browser available on their home system. At last, documents could be produced for universal, machine independent consumption.

There is a new language being developed that will do for applications what Netscape does for documents -- Java. *Java allows transmission of executable programs to any computer connected to the network to be interpreted and played safely and securely in real-time.*¹² Not only will Java threaten Microsoft's empire, it will significantly affect the power needed in a home terminal. Through Java, software programs become terminal independent; they become network-based. No longer will you be limited by either the application programs or files resident on your home computer -- you can leverage the power and information available from the millions of computers attached to the network. As the power of the network goes up as the square of the number of computers connected to it, the Internet should have enough power, well, to balance my cheque book, anyway.

This leads to the concept of a hollowed-out computer, a terminal with only enough smarts to efficiently interact with the network. Preliminary versions are already being built.¹³ Sounds portable -- sounds ideally suited for wireless networks. Might be useful in a classroom.

IX. COMPUTER LITERACY IS IRRELEVANT

Returning to the multimedia concept, it is interesting to note that multimedia is a largely unidirectional phenomenon, i.e., from the computer to you. Getting from you to the computer is slightly less than multimedia, say a mouse click or maybe even a keystroke or two. At long last, the fields of artificial intelligence and speech recognition are starting to mature. The result should be more efficient and much richer interactions with the information highway. More importantly, making computer literacy irrelevant will make these highways, together with all their promise, available to everyone and obviate the concerns about a two-tiered information 'haves' and 'have-nots' society.

X. WE'VE ONLY JUST BEGUN

In a parable concerning the Emperor of China, the Emperor offered the inventor of chess any prize he desired. The inventor opted for a mere grain of rice on the first square of the chessboard, two grains on the second, four on the third, and so on. While the Emperor thought the request modest, a simple calculation shows that at square sixty-four, this would amount to enough rice to bury the entire planet. George Gilder points out that in terms of progress in electronics, we are on square thirty-two.¹⁴ Of course, while the Emperor could solve his

problem by beheading the inventor, the solutions to our information age problems are not so straightforward. Actually, we have no way of even knowing how big the 'chess' board is, if in fact, it is limited at all.

In terms of interesting times, we have only just begun.

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