Appendix

A. Predicting the Unpredictable: Technology and Society[17]

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I have been asked to examine the likely information based technologies that will arrive over the next decade. Note the decade time scale was my limitation since predicting outside that time frame is unlikely to be realistic. For each technology I will discuss what the impact will be on society with particular emphasis on the international aspects. I have chosen to organize this paper as a set of bullets rather than a narrative in the interest of clarity.

Each bullet will be proceeded by a date and a probability. These are my estimates of when the technology will attain large-scale deployment and how confident I feel it will actually achieve that deployment. I will also start with large scale technologies that have major national and international impact and then focus more on technologies that will directly impact the average citizen.

Ultra high speed all optical networks

With the steady progress in the technology that underlies optical networks it is now feasible to predict with some certainty the future directions. Terms like multiwave fiber networks with speeds in the 40-gigabit per wave and number of waves in the 100 range are not beyond the rational dreams of technologists. The inclusion of optical amplifiers makes it feasible even now to remain in the optical domain for continental distances. Current work in all optical switches strongly suggests that we may within the first decade of the 21st century achieve source to destination communications systems in which the signals

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remain entirely in the optical world. This raises a set of very interesting questions. Some of them are technical; some economic and some societal. I will examine each of these in turn. Multi-gigabit speeds have raised a whole new set of very difficult technical issues. Designing and building switching devices and interface devices, which can operate at these speeds, is not simple. It pushes both hardware design and VLSI technology to their limits. As a result, it has been necessary to take innovative architectural approaches to even hope to achieve speeds nearing a gigabit. Perhaps most interesting, though, is the conclusion that many of the ideas developed over the past twenty years in computer architecture, operating system design, and networking protocols seem to be ineffectual when applied to such high speeds. It is worth observing that these communication speeds are of the same order of magnitude as the main memory bus speeds of modern workstations. Thus it is not surprising that we have run into problems. When streams of data arrive at memory speeds, it becomes difficult, given the protocol systems currently in use, to get the data into memory, to allow the processor enough processing bandwidth to examine the data and move it, and still to have processing power left over for other tasks. I will not elaborate in this piece on the solution others and I have proposed for this problem. But basically, the solution revolves around the creation of a geographically dispersed distributed machine, the components of which would be interconnected by high-speed networks. This approach has been well documented.

What is more important than a particular solution is the challenge of facing a future in which gigabit speed networking will be considered slow, in which our communication infrastructure will consist of multi-gigabit, low error, high-latency networks, in which our processing units, while growing faster, will not keep up with increasing communication speeds. It is too easy to just remove a few instructions, hack a few cures, and show that one can operate not too badly at current speeds of communication. Perhaps this is equivalent to saying, "let the next generation solve the problem." I believe that there is a challenge facing the computer communication field of at least the same magnitude as the challenge the field faced in the very early days of networking. Attacking this problem will require the talents of people from every area of both the computer and communications fields--people willing to experiment and willing to face the same set of challenges those in the fifties faced with the then-new computers.

The major impact will be on industry. The changing of technologies forced by these ultra high speed all optical systems will expose existing industrial leaders to the same pressures and dangers that main frame manufacturers of hardware faced in the 70s. Many of them failed to respond to those challenges and several of the then leaders are no longer forces in the computer business. Attempting to continue to market buggy whips in the era of fast cars is a formula for becoming obsolete. The same is true of software. As the focus shifts from large slow, by future standards, operating systems and individual software applications to the lean and mean systems required by the future high-speed communications, many companies will be come obsolete. Applications will tend to become much more distributed as communications capabilities expand and costs, and maybe even price, decrease dramatically. Such changes will upset the current national industrial strengths and will push the need for increased numbers of IT trained people to compete in this New World. Countries which are fast to adopt, have a pool of investment capital and have a pool of flexible trained people will most likely emerge as the leaders.

In the communications space things are much more complicated. When one adds to the all-optical backbone infrastructure the increase in slower speed but still multi-megabit data rate technology capable of delivery to the last kilometer to the home and business, dramatic changes in the communications world becomes possible.

Bits to the Home/SOHO (small office/home office)

Over the past several years, a major change has started in the last kilometer connection area -- the so called local loop / last mile Prior to that time, the notion was that the last mile was either telephone services or cable TV services. In both cases they were monopoly-regulated services that offered little or no data services beyond what was available via analog modems. While ISDN was in theory deployed, for a number of reasons it failed to be a major player. The reasons were some technical -- ISDN still used the telephone local switch and tended to overload it and some economic -- prices were held high and deployment was sparse. In addition as analog modem technology matured the speed differential between it and ISDN narrowed.

Recently two technologies have become economically and regulatory feasible -- at least in the US. These have been TV cable based data services and the xDSL capabilities over the copper telephone wire. They both offer the potential of always connected multi-megabit two way data services to the home at prices, again in the USA, that are affordable for certainly the SOHO area and many homes.

These create the possibility of providing significant last mile access to the future optical wide area networks. A note: there is the possibility of optical connectivity directly to the home via plastic fiber, etc. However it is not clear that this is feasible economically due to the cost of installation in all but new concentrated construction. If it is feasible then things are just better and my following argument just gets more interesting.

What will be the impact on the public and industry of this enhanced last mile capability? Again it threatens to attack the business base of several important industries. The most susceptible to economic damage is the telephone industry. The ability to carry telephone traffic over packet switched networks has been amply demonstrated, even though in the current internet the performance is less than standard telephone quality. That differentiation will vanish on future technology internets and even now the capabilities of cable and xDSL strongly suggests that as a local telephone company bypass for at least non local calling, it could be deployed now. Since the capabilities to access these data services will tend to focus initially on the SOHO marketplace, a number of serious impacts suggest themselves.

Perhaps most serious is the draining of the long distance income and even local service fees that will be lost by the removal of the business use. That will most likely force the telephone companies to raise their fees. Such raised fees will impact more strongly on the less advantaged segment of the population. Also in the long run, the telephone industry wedded to circuit switched equipment with long life times will find itself in more and more financial difficulties as more efficient competition arises utilizing much cheaper technology. Since the telephone industry is both a large employer and in many countries a significant source of government monies, it is not at all clear how this will resolve itself. Attempts to preserve the old infrastructures will most likely cause decreased international competitiveness. While the telephone industry is threatened by new technology for the last mile, another threat is arising via wireless systems in the world / city and house.

Wireless and mobility

Wireless technology is one of the fastest growing areas of communications technology. For many years we have been offered the vision of being connected via a digital path at all times. Unfortunately for a long time the technology, regulators and the market place did not combine to deliver the promise. There are several new technologies coming into the marketplace and laboratories that may radically change the wireless world. First, and this is US centric, there are market forces at work that are changing the way wireless is used. The bulk tariffs that are now offered by almost every cellular carrier have changed the balance between the wire world and wireless cellular service. In many cases especially in urban areas the need for a wire line telephone is decreasing. The costs of wireless with a large allocation of talk time, about 600 to 1000 minutes per month with no toll charges and no roaming bring often the cost of cellular below that of wire service. That will have two effects. One is that again the cream market will be skimmed off the wire telephone service and what is left is the low margin lifeline service and second it will force the costs of conventional toll down to a level to match that of the flat rate cellular -- that is happening already. All this, at least at a nation level, will bring reduced costs and increased capability to the public and the advantages of wireless systems in emergencies, storms, etc.

Internationally life is a good deal more confused. The new GSM is moving along with several competitive systems. The only bright spot in my view is the fact that technology makes it feasible to produce handsets, which are multi-standard, capable. That is they will operate on any of the worldwide standards given of course the licensing authorities within the country allows their operation. The lack of a sensible roaming system makes it much more difficult to live in this environment internationally.

LEO, low earth orbit, systems such as Iridium are coming online and at some time in the future may reach a price point where it will force the rationalization of the normal cellular systems with respect to international roaming. The potential of satellite systems for high speed data is just being explored in the commercial world and one predicts a slow start due to the high initial investment required.

The role of data in the current generation of cellular wireless systems is at best secondary. However proposals for the next generation cell systems talk about data rates that could hit a megabit per second and higher largely due to the small cell size of future systems. In the arena of satellite systems, Hughes and others have been talking about Direct Broadcast systems that allow two way links with modest speed uplinks. Such systems are still not available and it is unknown what the price and performance will be. The use of satellites for multicast applications seems much more desirable than direct point to point usage. Systems under study use such multicasting for Snow Crash-like applications.

Satellites are by their nature transnational and thus raise all the issues of cultural identity, religious rules and national control. These will become ever more of an obstacle to the free exchange of material over networks, be they ground or earth orbit.

Home and personal networks

The wireless world is often focused at mobility in geographic distances such as cities, states etc. The advent of short range very inexpensive radio links such as Bluetooth and equivalent systems.

From http://www.sss-mag.com/ssnews.html#3:

Bluetooth technology highlights

- Based upon a small, high performance integrated radio transceiver, each of which is allocated a unique 48-bit address derived from the IEEE 802 standard.
- Operate in the unrestricted 2.45GHz free band, which is available globally although slight variation of location and width of band apply
- Range set at 10m to optimize for target market of mobile and business user
- Gross data rate 1Mbit/s, with second generation plans to increase to 2 Mbit/s
- One-to-one connections allow maximum data transfer rate of 721 kbits/s (3 voice channels)
- Uses packet switching protocol based on frequency hop scheme with 1600 hops/s to enable high performance in noisy radio environments. The entire available frequency spectrum is used with 79 hops of 1Mhz bandwidth, analogous to the IEEE 802.11 standard
- Low power consumption drawing only 0.3mA in standby mode enables maximum performance longevity for battery powered devices. During data transfer the maximum current drain is 30mA. However during pauses or at lower data rates the drain will be lower.

The technology represented by Bluetooth opens up a wide and exciting variety of applications. Essentially everything in a house can now be equipped with network access. Personal devices such as watches and calendars can communicate to other systems in the home and office. An ID card can become an active badge that identifies the user to the environment they are in. Locks can open, lights can come on and temperature can be set to an individual taste when they enter a room. (As a side comment the badge can require a PIN prior to becoming active so as to insure the rightful user is using it.). TV sets can restrict the program material depending on who is viewing. Thermostats can sense occupants, outside weather, etc., and properly adjust the house saving significant fuel.

More important is the ability for devices to organize themselves into interesting new systems. For example, a PC equipped with a Bluetooth can detect that the PDA (Pilot like personal device) belonging to me (via use of my personal ID card) and update its data base with new appointments etc. The possibilities are huge and will start a new round of innovation at a much more personal level that that of the PC.

As with each of the technologies I have mentioned there is a societal impact. The privacy of the individual will be constantly under attack. If I have an active ID card which constantly announced to all that will listen, or all that will ask, who and where I am, there is an excellent opportunity for massive violations of my privacy. Each of these threats to the individual has a corresponding technical solution and unfortunately the potential for these solutions to be blocked by national laws. For example, most of the applications envisioned by such wireless links would greatly benefit from or require strong encryption. Yet in many nations strong encryption is banned or controlled. Also many nations restrict the export of such technology and thus damage the marketplace for devices with that capability.

Computers

While I have focused my attention in this paper at communications technology since that is the arena where the most change will take place in the next decade, it would be inappropriate to ignore looking at computers and software.

The end of history in computers has often been predicted based on limits of line width, etc., on semiconductor devices. Each decade we predict the end of increased capability due to these effects and each decade it keeps growing. At least for the next 5 years we can expect increased speed and capability out of our microprocessors. Architectures that used to require rooms of equipment are now in a small chip. Further we see yet again the blending of software methodology with hardware architecture as computers that require complex and capable compilers are entering the marketplace. We can expect to see this sophistication increase and begin to see optical interconnects between components to overcome the limits of wire connections. Further we will see increased use of multi-processor architectures to gain increased performance from commodity components as well as increased capability to provide security on the chip. The limitations on computing, at least at the non-supercomputer end, will come from software.

A major limit to innovation has always been our ability to produce reliable working software. The scale of software systems enabled by the modern computer and communications systems has stressed our abilities to create such systems. This problem started in the 60s and has gotten worse. Further, as such systems have embedded themselves in critical tasks often managing life-supporting systems. This lack of a viable software engineering methodology is currently the major limit to the greater infusion of computers and communications into our society. Numerous attempts to understand the planning and development of large complex software systems have failed to achieve any meaningful success. The USA in its IT^2 research initiative will devote significant resources in an attempt to solve this problem. However the size and complexity of systems may out race our abilities under the best of circumstances to get software under control.

Repeated failures of key software systems even after the 2000 issues will have societal impact on people and nations. This impact ranges from the loss of credibility on the part of the public for computer based devices with increased pressure not to continue our technologically enables society up to and including massive damage done by nuclear plants and missile control systems which fail.

Some social comments

While I have been asked to address the technical issues and their impact on society, I can not finish this paper without making some social comments. These comments originally were made at a meeting of the AAAS in 1996 and are modified for 1999.

Cyber-rights

John Perry Barlow is credited with having observed that our Bill of Rights is but a local ordinance in Cyberspace. He was referring to the fact that the basic rights which we hold self evident in the USA are only self evident to our society and are not accepted worldwide. Similarly our notions of morality, law, right and wrong are European-centric and are not accepted uniformly worldwide. Our society is individually oriented. The rights of the individual often take priority over the rights of society as a whole. This view is certainly not a world wide view. Asia, especially Singapore, is fond of pointing out that the Asian view puts the group first and the individual is viewed in the light of what is good for the group. What side will Cyberspace citizens take in this very profound cultural argument? Can both views live compatibly in a closely coupled cyber-world?

In Cyberspace individual national laws and customs, which are often different and contradictory, may conspire to limit the ability of individuals and corporations to freely interchange information, ideas, images and spoken works even when those items are legal and appropriate in the nation of one of the participants. Many societies currently, for example, limit the availability of satellite dishes. Several governments have equated Internet access, along with the fax machine, as the prime vehicles for external disturbances to their control of their society and have stated that in the event of any future internal disturbances they will severe the internet connections rapidly. What will be the impact of such attitudes on international commerce and learning?

The privacy laws that many governments have reasonably instituted to protect their citizens from having their personal information flow outside the control of the laws of their nation raises many difficulties when on is engaged in a Internet environment. The establishment of directory structures which involve some nations' citizens may be in violation of the laws of that nation. Libel laws are traditionally national yet in Cyberspace, libel is instantaneous and globally damaging. Is there a notion of global liability? How do I sue a person in another nation? If I can, do we achieve the lowest common denominator? Is there a global right to privacy? How is it enforced? What happens to global commerce if there is not a common understanding?

Many nations and cultures have dramatically different perceptions of what is proper and not proper for its citizens to possess or to view. Consider an extreme case -- child pornography. We in the United States have strong laws which forbid the distribution. possession etc. of such material -- other cultures may not agree with us or have different notions of the control of such material. Suppose citizens of two such countries send each other such material and the material transits the United States; is stored on a US computer (without the knowledge of the owner of the computer) against the law? Can or should the US intercept such material and delete it, should they arrest the people when they next enter the US, should they close down the computer used to store the material?

Is there an international agreement on the transport of cryptographic material across national boundaries? Is there a right of innocent passage -- that is , it is bound for another nation and just stops for a short stay -- mail relays for example? What is the right of a nation to monitor the contents or addresses of electronic communications that is transiting their nation?

The cyber-economy

As the Internet becomes more a part of the everyday business of the nations, it will become more and more necessary for commerce to take place among the users of the infrastructure. We can expect in a very short period an international electronic marketplace where goods of all types -- merchandise, information, software etc. are being bought and sold.

Historically there has always been a need to create a way of paying for such goods in order to motivate the supply side of the marketplace. Currently our primitive electronic marketplaces have no very effective mechanisms for paying for goods.

This creates an interesting and exciting opportunity to examine just what is needed to supply a mechanism for the exchange of electronic currency and how such a mechanism can exist in a national and international arena.

The issues raised by the potential existence of an international electronic marketplace (IEM) are not limited to just how to pay for things. There is the need to have the equivalent of credit cards, checks and paper money with it various shades of traceability and privacy. There is the need for escrow mechanisms and international exchange etc.

The additional issues raised by the IEM include:

- The use of small payments as the mechanism for enabling the marketing of hypermedia documents where the links are access paths to updated and marketable property. The crossings of the links require the payment of a fee (electronically and capable of allowing very small payments). For example, having accessed the information once if I copy it and give it to a colleague I have lost the ability to search for sub-links and automatic updates.

- Authentication of sellers and buyers when necessary and the protection of that information when required

- Privacy and personal freedom issues as to what I buy and from whom.

- The integration of any such system into the domestic and international banking and funds transfer systems as well as the different laws and regulations of states, countries and needs of law enforcement
- The need to internationalize buyer protection laws.

Cyber-education

Nowhere are the challenges greater than in the possibilities that the Internet offers in education. There is no better way to create international understanding, friendship and exchange than communication and cooperation between schools and students all over the world at all levels. Education applications cover most potential uses of the Internet and impose demanding requirements on the infrastructure. Education is also an area where the public interest is evident.

The role of the universities in educating the citizens who will lead their nations into this future calls upon them to pioneer the exploration of the benefits to be gained as well as the problems to be faced in this new world. Exploration of the Modern Worldwide Multi-Campus University-University of Cyberspace-interacting with lower grade schools and continuing education to provide individual-centered lifelong learning, should therefore be included in the G-7 vision. The intent should be not to just perform experiments with exchange of courses over the network but rather to explore, understand and solve the complicated issues of inter-organizational operation, economics, national laws and tradition that must be solved in order to create such an extended University. Perhaps most important, however, we must understand how such an organization can enrich University life for the students as well as the faculty. The design of the University must address this issue with highest priority if it is to be a success.

A group of Universities strongly believe that the lessons to be learned from this effort will show the way for better understanding of how industry and governments can use the Internet. This effort will contribute to new strategic knowledge necessary to cope with the global structural change of the telecommunications, media and information industries which is expected to lead to an information society. This rapid change calls for extraordinary programs in research and education to provide the competence necessary in government, industry, among users and all parts of society. However, the most important outcome will be to create a new generation of future leaders who have lived and learned in the borderless world of the Internet and who thus will be better prepared to understand and control the structural changes being created by the information society in order to secure fuller more meaningful employment and social welfare for their people.