On the Emergence of New Computer Technologies

Olumuyiwa Sunday Asaolu
Department of Industrial & Information Engineering, University of Tennessee, Knoxville, TN, USA
Tel. +1 865 974 3349
Fax +1 865 974 0588.
sasaolu@utk.edu

ABSTRACT

This work presents a review of the development and application of computers. It traces the highlights of emergent computing technologies shaping our world. Recent trends in hardware and software deployment are chronicled as well as their impact on various segments of the society. The expectations for the future are also discussed along with security concerns. It is concluded that a major technological challenge being addressed is making information and computing power accessible anytime, anywhere and on any device. We note that worthwhile solutions will also address efficiency and security concerns.

Keywords:
Computer, Technology, Internet, ICT, New trends

Introduction

The computer has been widely deployed within the last decade to almost every conceivable sector of human endeavor. Improvement to computing processes, applications and tools are developed regularly as well as new products and services. This write up will offer information on evolving trends. A useful metric for the rate of technological change is the average period during which speed or capacity doubles or, more or less equivalently, halves in price. For storage, networks, and computing power, these periods are around 12, 9, and 18 months, respectively (Foster 2002). Such is the growth rate within the information and communication technologies (ICT) industry in recent years.

Definitions

The Webster's Dictionary (2002) defines "*New*" as that which just evolved, first-timer, recently discovered or learned, previously unknown or that which is unfamiliar and does not conform to established tradition. This succinct definition captures the context in which we use the word. Asaolu (2001) extended the MSE (2000) definition by stating that, "a computer is a programmable electro-mechanical device, which accepts data and processes such according to some prescribed instructions by performing calculations on numerical data or by compiling and correlating other forms of data. It supplies the result in a specified format, as useful information or as signals to control other machines or processes." Technology refers to applied science, standardized means and ways of adapting scientific principles for the design, production and maintenance of goods and services to meet human needs. It includes information, techniques and tools with which people utilize the material resources of their environment to satisfy their needs (Olunloyo 1997).

In the twentieth century, scientists and engineers collaborated to devise new ways of capturing, processing, storing, transporting and displaying information. From the Post-office and telegraph to mobile phones on one hand, and from the television, the computer and satellite on the other, Information and Communication Technologies merged to become a distinct field popularly referred to with the acronym ICT. Its development and effect on society have been profound. It has impacted the way we work or play. ICT encompasses all those technologies that enable the handling of information and facilitate different forms of communication among human actors, between human beings and electronic systems and among electronic systems. These ICT according to Hamelink (1997) include:

> *"Capturing technologies* to collect and convert information to digital input. These produced the keyboard, mice, joystick, touch-screens, voice recognition systems, bar code scanners, image scanners and palm-size camcorders.
>
> *Storage technologies* to store and retrieve information in digital form. These led to magnetic tapes, floppy and hard disks, RAM disks, optical disks such as CD-ROMs/DVD, smart cards, memory sticks, etc.
>
> *Processing technologies*, creating the systems and applications software required for digital ICT.

Communication technologies producing devices, methods and networks to transmit information in digital form. These include digital broadcasting, cellular networks, LANs and WANs (e.g. intranets and the Internet), modems, fax machines, etc.
Display technologies, which create a variety of output devices for the display of digitized information. Examples are computer monitors, printers and plotters, DVD, TiVO, voice synthesizers and virtual reality goggles / helmets."

Evolution of Technology

From the use of fingers and toes, to stones and bones, man proceeded to invent several apparatus that led to the modern machine for computing. The computer of today (or tomorrow) is light-years ahead of any that would have been conceived by Leonardo da Vinci. The evolution of ICT has spanned several centuries; the advancement within the last half-century is truly enormous. Information signals (sound/voice and data –text or pictures) converged into digital form –the binary language of computers and, could thus be transmitted for shared usage through communication devices and other electronic products. Hence we had convergence of and, development of multifunctional technological products that offered users mobility and shareability of services.

The military, the corporate bodies and the innovative entrepreneur have seen to the ascent of technology over the ages. The technological environment changes so drastically that a human generation witnesses multiple technological generations. Technology has not only brought increased standard of living, it has also brought along competition among nations seeking dominance in the new world order. It is even argued that ICT growth also enabled the dark sides of computing such as privacy intrusions, data destructions and easier means to spread moral perversions and ideologies.

Characteristics of Technology

- present in all cultures
- knowledge based and involves application of knowledge to solve problems
- it is accumulative
- it is fundamental to humanity and survival
- it alters culture and society
- it is observable and future oriented
- it seeks a harmonious relationship between human life and nature
- it is an extension of human body and faculties

Levels of Technology

Low-level technology (before 3200 BC)
- characterized by basic primitive tools and machines be it natural, adapted or manufactured
- tools include bows, arrows, spears, stone hammer, store axe etc
- machines include lever, wedge inclined plane, pulley, wheel and axe etc.

Intermediate-level technology (3500 BC to date)
- characterized by tool manufacture for multiple purposes in different sizes by use of different materials
- intermediate level machines differ from primitive ones by role of prime movers such as wind, water and other natural forces as well as steam engines, the electric motor, steam turbines, internal combustion diesel engine etc.

High-level technology (1950 AD to date)
- characterized by high level tools (usually automated) and machines, emphasis of hi-tech is more on assisting the mind not the body
- high level technology further subdivided into 'Fordist' and ICT depending on the level of emphasis placed on standardization and automation on the one part (Fordist) or information and communication technology on the other (ICT). These features are enumerated in Table 1.

ICT is appreciated when these technologies help users to be efficiently productive or relaxed (entertained), this means the user must feel a sense of security, mastery and accomplishment.

Table 1. Comparison of high level technologies

Fordist (Old)	ICT (New)
Energy-intensive	Information-intensive
Standardized	Customized
Rather stable product mix	Rapid changes in product mix
Dedicated plant and equipment	Flexible production systems
Automation	Systemation
Single firm	Networks
Hierarchical management structures	Flat horizontal management structures
Departmental	Integrated
Product with service	Service with products
Centralization	Distributed intelligence
Specialized skills	Multi-skilling
Minimal training requirements	Continuous training and re-training
Adversarial industrial relations; collective agreements codify provisional armistices	Moves towards long-term consultative and participative industrial relations
Government control and planning and sometimes ownership	Government information, regulation, coordination, and 'Vision'
Capital intensive (funded by the government or through loans, etc.)	Phased investment (by individuals, venture capitalists, etc.)
Emphasis on full-time employment for adult (16-65) male workers	More flexible hours and involvement of part-time workers and post-retirement people

How and when are we to invest in new technologies?

According to Olunloyo (2003), the objective is to maximize returns on investment and seek out technologies that;

- Require short diffusion time and high penetration within economy
- Require modest capital outlay for high returns
- Benefits from convergence of technical infrastructure within the economy
- Allow investment to stimulate technological chain reaction

Technology brings development. To be sure, when technology is disruptive, it beckons at investment; otherwise investment rides on product demand to seek out the appropriate technology. Investment into new base technologies eventually leads to industrial waves which, in turn are presumed to produce economic waves that could be described for example by Kondratieff's Cycles (Godet 2000).

Computers and the Internet

The computer has indeed come a long way. Initial key contributors to this concept and product include John Napier, Blaise Pascal, Gottfried von Leibniz, Joseph Jacquard, Charles Babbage, Herman Hollerith, John V. Atanasoff, Clifford Berry, Konrad Zuse, Howard Aiken, John Mauchly, Presper Eckert, Remington Rand, Alan Turing and John von Neumann to name a few (Parker 2003). The computer (machine and accessories) constitute *hardware* while the programs (coded instructions) used for various purposes and tasks are known as *software*. The following computing eras are widely acknowledged:

- First Generation Computers (1939-1954) - vacuum tube based.
- Second Generation Computers (1954 -1959) – transistor based.
- Third Generation Computers (1959 -1971) – integrated circuit based.
- Fourth Generation Computers (1971-Present) – microprocessor based.
- Fifth Generation Computers (Present and Beyond) – offers portability, embedded intelligence and distributed computing.

The Internet is a vast and complex network of networks that connects computers around the world; it is changing social, political, and economic structures, and in many ways obviating geographic boundaries. Its history is well documented (WebDevelopers 2005). The Internet began as a U.S. Department of Defense (DoD) project to interconnect or network DoD-funded research sites in the U.S. in the mid 1960s through the Advanced Research

Projects Agency (ARPA). The fundamental technology that makes the Internet (initially ARPANET) work is called *packet switching*, a data network in which all components (i.e., hosts and switches) operate independently, eliminating single point-of-failure problems. In addition, network communication resources appear to be dedicated to individual users but, in fact, statistical multiplexing and an upper limit on the size of a transmitted entity result in fast, economical networks. It is based on Transmission Control Protocol (TCP) for end-to-end network communication and Internet Protocol (IP) for routing packets and device-to-device communication. There are companies described as Internet Service Providers, which handle all the technicalities and provide (connection) access for subscribing computer users. Such companies use various modes of electronic data delivery and / or communication: from telephone dial-up to wireless satellite transmission.

Some of the popular offshoots or by-products of the Internet include;

- *The World Wide Web or WWW* – a collection of linked electronic files\documents offering vast information on any subject, residing on numerous accessible servers. Indexing services and Search Engines enhance their usage. The WWW is itself based on the hypertext and file transfer protocols (http and ftp).
- *E-mail or electronic mail*, which has been estimated to have a superiority ratio of 240:1 to its *fax* predecessor. E-mail has almost totally taken over electronic document transmission and relegated the delivery of written or bulk printed packages to the conventional post-office.
- *Electronic-chat and messaging***,** this system allows remote users to participate in real-time textual, graphic and voice conversations. Such free services offered by multinationals such as Yahoo!, AOL, MSN, Google, etc. (who derive the substantial portion of their revenue from advertisers and other subscribers services) has opened up a new vista in modern communications. Newsgroups or electronic bulletin boards have developed as another method of communication on the Internet. There are thousands of different newsgroups, each dedicated to the discussion of a different topic. Each newsgroup has its own designated subject area that people in that group are interested in discussing. Then, within each group "threads" or conversations about an aspect of the topic will emerge. Members in the newsgroups communicate by "posting" (mailing) messages to the newsgroup.
- *Internet-telephony* based on Voice over Internet Protocol (VoIP). This allows making telephone calls over the Internet; it effectively transforms expensive international calls into almost cheap local calls!
- *Interactive Content Delivery Services*; these have been harnessed to develop new paradigms such as e-learning, e-governance, e-commerce, e-dating, e-conferencing, etc. These online services allow people to offer and receive distant education, business transactions, meetings, news and reports, medical and other consultations, etc. They are usually implemented as Web Portals having Frequently Asked Questions (FAQ), Feedback and Discussion Forum sections.

There is a closing gap between introduction of technology and its diffusion or penetration as shown in Table 2. This is a delight to the liberal world and chagrin to repressive governments.

Table 2. Rate of Penetration of New Technology

Product	**Time taken to reach 60 million people**
Radio	30 years
Television	15 years
Internet	3 years

Recent Trends

Ironically, change is reputed to be the only constant in the universe. This explains why the ICT innovations of the past are getting antiquated and, why our present prided ICT inventions will someday become obsolete.

Hardware Progressions

Hardware core components have been progressively improved over the last century to electronic systems utilizing the vacuum tube, then the transistor, to the integrated circuit and then the microprocessor. The IBM Corporation is to computing what the Ford Motor Company was to the automotive industry; it introduced and standardized affordable mass production. In the industrialized nations, most people have access to a computer at work or at home. Many even have laptops and / or mobile phones. The developing nations are also trying to bridge the digital-divide, which is expected to be easier to catch-up on than the industrial revolution.

Intel Corporation and Advanced Micro Devices Incorporation (AMD) are leading industry rivals that continually break the record for microprocessor speed with their respective products. The miniaturization of the computer is an obsession. This is demonstrated through the development of portable devices (PDAs), embedded systems, palm-tops, mobile computing, etc. The Tablet PC for instance, provides all the power of a standard notebook plus additional features that improve mobility including pen-input, light form-factors, handwriting and speech recognition.

The mainframe and supercomputing aspect is also vigorously pursued. Developed countries use supercomputers in a variety of industrial and economic fields. These are used to make financial and economic forecasts, to explore oil and gas deposits, to make weather forecasts and climate changes, to solve traffic problems in big cities, to administer logistics at large corporations, to perform various calculations for aerodynamics. They are also used in the pharmaceutical industry, human genetics, in astronomy, for controlled nuclear fusion, the modeling of explosions and nuclear tests and other complex or calculation intensive areas.

With performance almost double that of the Earth Simulator, in Yokohama, Japan, IBM's Blue Gene/L was recently ranked first on the Top500 list of the world's fastest supercomputers (PC World 2004). Not to be outdone, the Oakridge National Laboratory of USA (ORNL) is planning to build an even faster computer. Also, Russia has created a new supercomputing machine Skif K-1000, which is presently (December 2004) described as the most powerful computing device in Eastern Europe.

'Electronic mutation' is now a factor for the survival of several computer hardware components. For instance, the familiar Parallel port used for connecting Printers may soon give way completely to the Universal Serial Bus (USB) port. Flat screens are replacing the conventional monitor, radio and television tuning adapters have been developed for the PC. The computer has been adapted for both office and home use. It is not only a work tool or assistant but is also a multimedia entertainment centre for playing games, music and video. Better and cheaper PC accessories are released daily such as powerful speakers and web camcorders.

Software Progressions

A computer programming language is a formal notation for precisely describing and encoding algorithmic solutions to problems. An algorithm is simply a terminal, step-by-step procedure for actualizing a task. The major software that serves as the primary user-interface and controls the management of all tasks and system resources is known as the Operating System (OS). Other application software are mostly end-user utilities. From the punched cards of the Jacquard loom, programming has equally evolved with improvements in hardware design. Programmers have used Machine, Assembly and High Level (human like) languages. Different programming languages have constructs to support facilities needed for solving problems in specific domains. For example, COBOL has support for solving business related problems, C for systems programming problems, FORTRAN (and later MATLAB, LABVIEW, etc.) for scientific computing and, Lisp/Prolog for Artificial Intelligence applications. CADD-CIM software packages like AutoDesk's AutoCAD® were developed for integration with CNC machines. Although Apple Macintosh introduced software with graphical user interface (GUI), it was Microsoft Windows® OS and compatible products that proved more successful in the market place. Visual tools such as Microsoft Visual Basic®, Borland Delphi®, etc. were introduced for rapid application development. Hypertext Markup Language (HTML) and its new variants such as Extensible Markup Language (XML) and Wireless Markup Language (WML) were developed for accessing the Internet from PC and mobile devices. Lately, Sun Microsystems Java® has been touted as a more portable and robust development system.

There are two competing models in the software arena: proprietary and open-source solutions. Software (OS and other programs) that are copyrighted and offered (mostly commercially) under non-disclosure agreements is usually licensed by proprietary owners \ developers to end-users while those that are given out (mostly free) with accompanying source code for User modification are termed open-source. UNIX and Microsoft Windows® (and their derivatives) are the two dominant operating systems for which application programs are developed. Computing is being applied to virtually all areas of human endeavor such as communication, education, design and manufacturing, banking, commerce, entertainment, healthcare, sports, security, warfare, governance, weather studies and forecast, traffic management and transportation, outer space exploration, etc. The computer is one ubiquitous tool the modern world cannot do without.

Originally, computing was restricted to symbolic logic and the evaluation of mathematical expressions. In recent decades, new intelligent computational techniques, paradigms and applications have evolved such as Expert

Systems, Decision Support Systems, etc. For example, an expert system is an interactive-computer based decision tool that uses both facts and heuristics to solve difficult decision problems based on knowledge from an expert. Such knowledge is encoded using *If-Then* rules. There is also implementation of Fuzzy Logic (and reasoning), which is a scientific methodology for handling uncertainty and imprecision (Zadeh 1965). Fuzzy modeling gives a broader class of methods of granular information processing and knowledge representation. Another trend is Artificial Neural Networks (ANN). This is software that models the human process of learning and remembering. ANN involves a simulation of the human brain (consisting of multi-connected neurons) to model and predict the dynamics of an unknown system from sample sets of input-output data without explicitly determining the underlying relationships. ANN are trained by exposing them to samples, enabling them to recognize patterns. Also, the biological theory of evolution has inspired computational models such as Genetic Algorithm (GA) and its variants. A Genetic Algorithm is a directed random search technique that can find the global optimum solution in complex multidimensional search spaces. In this scheme, potential solutions constitute the population of the ecosystem, each individual member is manipulated (based on fitness criteria) by evolutionary operators to eliminate the 'unfit' and propagate the best ones. After several generations (iterations), mutated offspring converge to the solution (Gorzalczany 2002). Computational hybrids include the Neuro-Fuzzy systems, Neural GAs and, Fuzzified GAs, which combines the processing and predictive power of the various models (Pham & Pham 2001).

Peopleware Progressions

It has been suggested that the people who develop, manage and / or use the computer constitutes another important aspect described as *Peopleware* (Asaolu 2001). This takes cognizance of those that deploy and utilize computers as well as how they do so. The first computers were centrally located machines at specific organizations or research facilities. Access was naturally limited. With the miniaturization, reduced costs and mass production by IBM Corporation in the 1980s, more and more people have access to personal computers (PCs). Initially, software was designed to run on single PCs, with more users and the need for sharing of computing resources (such as files, printers, etc.) the issue of *networked* applications arose. The concept of a master machine (Server) to which others were connected and serviced (Clients \ Workstations) was implemented. While this proved successful, bottlenecks and limitations were soon discovered in this local networks or *intranets*. The US military and some scientists decided to create something much bigger and better that eventually evolved as the earlier described Internet. Although computer power, data storage, and communication continue to improve exponentially, computational resources are failing to keep up with what scientists' demand of them. A new technological adaptation is *Grid Computing* – this links and uses (dedicated or the idle time and processing power of) several participating computers on an intranet or the Internet to solve complex computational problems (BBC News 2003). By providing scalable, secure, high-performance mechanisms for discovering and negotiating access to remote resources, the Grid promises to make it possible for scientific collaborations to share resources on an unprecedented scale, and for geographically distributed groups to work together in ways that were previously impossible.

Other recent technologies include;

- *Short Message Service* (SMS) is the traditional e-mail of the wireless community. It has just been upgraded into Multimedia Message Service (MMS).
- *Bluetooth* is described by Ridgeway (2002) as embedded technology in electronic appliances; it is designed to create short-range wireless connectivity between separate devices. Stability within a noisy radio environment is achieved through a frequency hopping approach, which enables the module to avoid interference from other signals.
- *WiFi* or wireless fidelity is meant to be used generically when referring of any type of 802.11 network operating in the 2.4 GHz spectrum with a bandwidth of 11 Mbps. It is promoted by the Wi-Fi Alliance, a nonprofit international association formed in 1999 to certify interoperability of wireless Local Area Network products based on IEEE 802.11 specification.

Indeed, several consortia are proposing and implementing new methodologies / standards for wireless communication between electronic devices, for example in creating a network between a headphone, camera and printer or between a refrigerator, an ATM and a grocery store. While there is much speculation about the intelligence and capability of such new technologies, some functional applications are already commercially available. For instance, human language translation systems are a veritable area of research and, of recent has seen the deployment of mobile kits offering limited speech-to-speech translation.

Security Issues

There is also a lot going on for and against the dark sides of computing. *Bugs* are ancient but *Hackers, spammers, phishers, pharmers as well as spyware, virus and worm writers*, etc. are recent entrants into the computing vocabulary. Industry security experts and individual computer users strive to stay ahead of the next (potential) attack. Bugs refer to computer errors that were either undetected during hardware or software design or to known issues for which adequate work-arounds could not be proffered. Hackers break into supposedly secure computing systems usually for the fun of in or to steal information for espionage or merchandizing purposes. Spammers send mass (numerous) unsolicited e-mail to Internet users usually as a means of advertising. The situation reached such alarming proportions that in 2003, the US government passed the anti-spam law that makes sending unwarranted, assaulting and unidentifiable / misleading e-mails, illegal. Phishers create near-clones of financial or other commercial or governmental websites to trick and defraud unsuspecting people; they usually embed such website links in spam (e-mail). Pharmers are subtler, they "poison" or directly hijack local DNS servers by redirecting Web requests elsewhere –at times to a near-clone site. The browser is unaware of the diversion; the user may think the proper site is being visited and disclose personal information to identity thieves. Hookers or spyware developers create spy software and crawlers that automatically perform tasks and operations without the computer owners' permission; such as sending out information, displaying advertising or downloading data. Virus and worm writers produce destructive and self-replicating software that cram, slow down and eventually crash computer systems. Given all these, security is a big issue in computing with several firms and government agencies dedicated to countering the 'bad folks.' Operating System manufacturers together with computer anti-virus and *firewall* protection developers keep 'discovering and patching' dangers and security holes against which the industry must be protected. Also, privacy advocates continue to monitor developments in Biometrics application to prevent real and, imagined abuses. This is pertinent since Biometrics is the automated use of physiological or behavioral characteristics to determine or verify human identity. The financial, legal and other operational costs of computing faults and vices are enormous. Consequently there is increased research for better authentication, encryption and data processing algorithms.

Futuristic Devices and Applications

Now and in the future, hardware and software developers should build products that better support human needs and that are usable at any bandwidth. The old computing was about what the computer can do; the new computing is about what users can do (Shneiderman 2002). Though computers become more powerful and versatile, the knowledge and skills required to use it are easier to acquire and more accessible to the populace. Factors that facilitate groundbreaking and immensely successful or 'killer' applications include:

- A growing and aging population with shifting demographics
- Technology availability from continuously funded research
- Affordability / price
- Need (real or perceived)

Web browser based applications and wireless mobile computing might become the dominant forms of computing in the next decade, and proper support for it will require re-thinking several aspects of software design. We may not operate the paperless office until prolonged reading on the screen is pleasant to the eyes and more enriching than reading hardcopies. Who knows, humans may someday have embedded chips in our bodies to download, process and transmit information. The research for this is already on (Witt 1999). Eventually mankind could be self-wired as the '*last computer*.' The ban on physiological human cloning does not totally eradicate ethical problems if cybernetic organisms are allowed (embedding electronic systems in humans to create bionic or superhuman beings). From 3D modeling to simulation and virtual tours, man is devising smart devices for intelligent buildings, autonomous vehicles, and is working on producing more intelligent robots so that he could have time to embark on commercial space tourism and inter-planetary vacations. To this end, the record-breaking SpaceShipOne technology has been licensed by Virgin Airlines, this would facilitate commercial Space Travel by modified conventional aircraft (Microcom 2004).

Within the last few decades, contrasting enhancements were added to the home; for example answering machines for cordless telephones, the microwave for refrigerators, the all-in-one printer (fax, copier, photograph and document printer) for the computer, the VCR and DVD player for television, etc. In the not too distant future, the average person will possess more real, smart multifunctional utilities (car, phones, wrist-watches, etc.) than the presently seen special-effects artifacts in James Bond movies. With nanotechnology comes improvement in the production of synthetic organs, laser surgeries, wonder-drugs and the promise of increased and qualitative longevity. Centuries ago, those who thought of the possibility of space travel for humans or

development of television like devices were accused of superstition and regarded as dreamers. These concepts are however, present realities. It might not be stupendous to await the day that telepathy or teleporty would leave the realm of science-fiction for real and everyday happenstance because mankind has neither discovered nor harnesses all the forces and laws in nature.

The impact of new computer technologies

All nations seek the production or adoption of new ICT that facilitate sustainable development. However, digital technology comes with its own downsides and risks. For example, unforeseen electric power outage (in developed economies) leads to chaotic or paralyzed situations while such failure lasts. It is a truism to acknowledge that computing advances and strengths are accompanied by corresponding levels of vulnerability. Developing countries are greatly benefiting from ICT not only from the deployment for social integration and educational purposes but also from commercial returns. India is the classic success story of creating wealth through 'outsourcing' – the offshore contracting of computing jobs to cheaper but highly skilled labor markets. New ICT have impacted the development of new economic paradigms such as just-in-time (JIT) delivery and TINA (there is no alternative to globalization and liberalization). Notable world bodies such as the UNESCO and several professional organizations are assisting nations, particularly developing nations to acquire or develop both the infrastructure and the expertise necessary for ICT. For example, Nigeria has received financial and material (in the form of ICT derivatives) aids worth millions of dollars towards the conduct of her proposed 2005 census. Also, Paradigm Lingua, the author's award-winning word-processor and translator for Nigerian languages has impacted electronic publishing in Nigeria (Asaolu 2003).

Funded, focused organizational or institutional research and development leads to new break-throughs, new patents, new products, new trademarks, new markets, new clients, new awards, etc. The competition is stiff but the rewards are often satisfying. However, not all new technologies are well received or become successful. A technology can only be described and its significance appreciated in the context of its uses and its users. New ICT means that fore-runners must create new standards, governments must introduce new regulatory practices (such as cyber law for Internet crime, copyright enforcement for protection of intellectual property, etc.), companies must re-train workers and acquire new products \ services especially if the existing system becomes inadequate, colleges need to revise curriculum and, consumers must make new choices. New studies would also normally be required to assess the environmental and sociological impacts. For individual workers in the ICT sector, advancement and perhaps survival is synonymous with continual skill acquisition (Acemoglu 1998). New occupations and job titles have been created. Even e-literacy or computer literary has become a prerequisite for job applicants in the developing nations. For researchers, sifting through materials from electronic libraries is a new daunting task, not finding those materials in the first place from physical libraries or ordering and waiting for paper prints! Homework, assignments and projects can be researched, written (typed) and produced (printed) on the computer desk at home, school or a business centre (cybercafé). This is facilitated by new web services such as Google® Scholar and Google® Answers from the developers of the Internet's most successful Search Engine. The former allows a free search of scholarly publications across various institutional and publishing repositories while the latter is a venture whereby 'Google® experts' provide answers to a subscribers' question for a fee.

Developers have realized the need to customize new ICT for various segments of the society. For example, there exist configurations of the PC as an office computer or the home computer and, their respective operating systems and software. Interestingly, this line can be thickened or thinned by the user who may decide to work from home (Venkatesh 1996). Children' access to new technologies is improving as they are targeted with recreational and educational products. There are also products specifically designed for the elderly to aid mobility and frail / failing body organs. Usage across gender is becoming equitable as more women are utilizing ICT products especially on the home front. Physically challenged individuals (e.g. the deaf or the blind) are now taken into consideration in the development of ICT product versions as equal opportunities are promoted in the society. Even prisoners have limited or regulated access to ICT services in most countries. The modern broadcasting media is highly sophisticated and has universal coverage and reach. Everybody is involved. At last, the world has become a *global village*.

Conclusions

All aspects of computer technology are dynamic. Innovations are reported almost on a daily basis from both academic and industrial players. Even the end-users contribute new ways of deploying existing tools. The World Wide Web and other Internet technologies serve to store and distribute such services and information. The

prevailing technological challenge being addressed is making information and computing power accessible anytime, anywhere and on any device. A higher goal seems to be the development of a human-wearable chip or card that stores all personal information and can be used to manage all kinds of transactions on all computational platforms. Meanwhile, database systems on wired computers are giving way to knowledge base systems on wireless mobile devices. All these mean that data storage and processing must be more efficient and secure. Security issues are now a major concern because more interactions and transactions are effected daily, by more people adapting computing technologies.

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