Research and Development in Information and Communications Technologies: Challenges, Trends, and Recommendations

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Abstract

This paper presents a review of recent developments, issues, trends and challenges of communications and IT technologies. We will show how to change the telecommunications systems' design and adopt new technologies and practices that are significantly different from the past. The carriers of communications networks have to choose between going to the new business or keeping the old business. These data telecommunication networks will be very different from the past voice oriented telecom networks. In computing and computer technologies, there is a need to organize and program computers using more efficient methods than current paradigms in order to obtain a scalable computation power. This is needed to meet the challenges and needs of the 21st century. We will address the issues related to the security of communications and information systems as well as review suggested solutions. Finally, the paper will present suggested policies and plans that apply to the MENA region, in order to bridge the digital divide in research and development in ICT and in turn improve the economical and social standards of its citizens.

Key words: Communications, information technology, wireless systems, MENA region, research and development in ICT, ATM networks, optical networking, DWDM, high-speed networking.

I. Introduction:

The last two decades have witnessed amazing developments and breakthroughs in information technology, computer communication, software technology, computing and computers, Internet and World Wide Web (WWW) technology and others. Such technologies have impacted all aspects of our life and have made our world a global village. The progress in these technologies has continued at a rapid pace and has made economical, social, cultural, educational, psychological, political, military impacts, among others [1-10].

With the exponential growth in data and traffic, telecommunications service providers are suddenly finding that their real future is in transporting data. However, there are major differences in the way data and voice networks are designed. The dynamic content-driven surge of the WWW is taking data telecommunication systems into the next millennium beyond the previous benchmark set by the ubiquitous voice networks encircle our planet. Clearly, there is a need to change the telecommunications systems' design and adopt new technologies and practices that are significantly different from the past. These data telecommunications networks will be very different from the past voice oriented telecom networks.

The Internet and (WWW) have moved computing, communications, and IT applications, in general, to the main stream of users. Such technologies are being used on a daily basis in applications such as e-commerce, e-business, e-government, e-ticketing, etc. The consequences of access to these facilities by unauthorized users range from inconvenience to massive loss of money or catastrophe. This means computers and networks security is becoming a vital issue in the 21st century. There is a multi-billion dollar industry in this discipline.

The laptop computer used today by a single user has a computation power of over one hundred times than that of the mainframe computer that was used about fifteen years ago by tens of users with a significant improvement in performance and significant reduction in weight. Although computational power is abundant these days, there are applications that require massive computations such as oil exploration, environment protection, weather forecasting, geological surveying, modeling and simulation, military maneuvering and training among others. Clearly, there is a need to organize and program computers in more efficient parallel and distributed topologies than current paradigms to obtain scalable computation power to meet the grand challenging applications of the 21st century [8-10].

Progress in computer networks and telecommunications systems is also amazing. There are new efficient switching techniques, networks topologies, protocols, analysis and simulation methodologies, benchmarking and traffic engineering techniques, wireless and cellular techniques, encryption and authentication schemes, Gigabit Ethernet, high speed routers, high performance ATM technologies including ATM switches that can switch terabits per second, high bandwidth connection to the Internet, Web-based computing and communications, among others.

The release of the World Wide Web (WWW) in the early 1990’s has moved the Internet and telecommunications to the mainstream. The Web has also served as a platform for enabling and deploying hundreds of applications, including online stock trading, and banking, e-commerce, streamed multimedia services, e-learning, and information retrieval services.

ATM (Asynchronous Transfer Mode) technology has been deployed very aggressively within both telephone networks and the Internet backbones. Such new technologies and applications require performance evaluation at various phases.

In this paper, we will review recent developments, issues, trends and challenges of these information and communications technologies. We will shed some light on potential techniques to solve the related technical issues including our own contributions. Also, we will present suggested policies and plans that apply to the MENA region, in order to bridge the digital divide in research and development in ICT.

II. Current Issues and Trends

The main current issues in Information and communications technology are:

- Security and Authentication
- Quality of Service (QoS)
- Traffic Engineering
- DWDM
- Standards
- Bandwidth
- Data, Image and Video Compression
- Viruses and Worms
- Challenges of 3G Wireless Communications Systems

In order to resolve and tackle these problems several proposals and research directions have been initiated. This has lead to several trends in these technologies. Among these are [11-17]:

<u>Trend 1: More Capacity</u>

The trend these days is that silicon capacity is doubling every 1.5 Years (18 months). Originally, Gordon Moore, co-founder of Intel Corporation, found out in 1965 that the number of transistors that could be put on a single chip was doubling every year and correctly predicted that this rate would continue into the near future. In the 1970's he observed that the pace has slowed down to double every 18 months and this rate has been sustained since then [17]. The consequences of Moore's Law are profound: (a) The cost of memory devices and computer logic has fallen at a dramatic rate, (b) due to the fact that logic and memory devices are placed closer together on state-of-the art densely packed chips, the electrical path length is shortened, which has increased the operating speeds, (c) the computer has become smaller making it convenient to place it on a lap or even wear it, e.g. wearable computers, (d) there is a reduction in power and cooling requirements, and (e) the required circuitry has become much more reliable due to the fact that the interconnections on integrated circuits are much more reliable than solder connections.

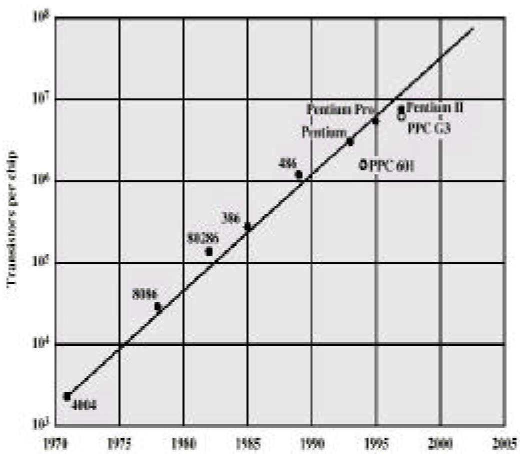

Figure 1. Growth in CPU transistor Count [17].

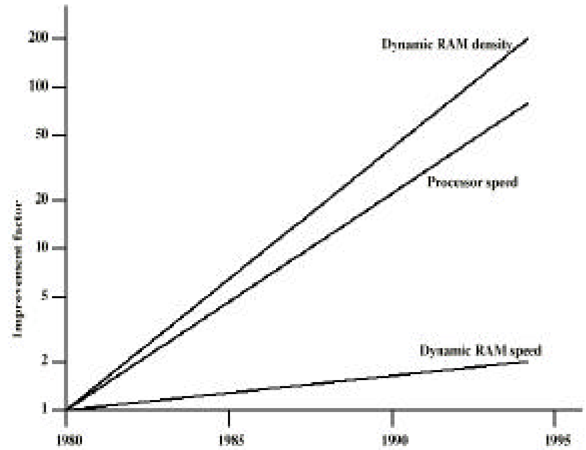

Figure 2. Dynamic memory and processor relationship [17].

As for the storage capacity, it is doubling every Year. While the processor computational power has raced at a breakthrough speed, other critical components are still slow. There is still a speed gap between the processor (CPU) and the main memory. Cache memory has been devised to bridge the speed gap; however, we still need more efficient algorithms for cache replacement and for write back techniques [Obaidat and Khalid]. We devised an efficient replacement technique to improve over LRU policy and called it, KORA: Khalid Obaidat Replacement Algorithm, which provided average enhancements of about 8% over LRU.

As for wave division multiplexing, WDM, that is being used in optical communications, it was reported in 1998 that it is possible to multiplex 16 Wavelengths/Fiber. This can lead to 2.5 Gbps /Wavelength, ⇒ 40 Gbps/Fiber. In three years, it is expected that we can get 1022 Wavelengths/Fiber, 40 Gbps/Wavelength ⇒ 40,000 Gbps/Fiber. Clearly, the growth rate is 1000 in five years. Currently, the networking capacity is doubling every 9 months due to new technologies and algorithms in telecommunications and networking.

Trend 2: More Traffic/Activity

Number of Internet hosts is growing in a super exponential manner. There is also an increase in Inter-LAN traffic at a rate ranging from 100% to 500% per year. The capacity of bridges, routers, hubs, gateways, and switches required to transport, switch, and route that data must increase in the same proportion. The traffic per host is increasing due to the use of broadband access techniques such as the ADSL/XDSL, and Cable Modem techniques as well as T1 and T3. The projections of network traffic turn out to be lower than actual. The User-User Net traffic is doubling every 4 months [15].

Trend 3: Traffic is Greater than Capacity
The traffic being carried in the intranets and Internet is greater than the capacities of these networks. This means that the bandwidth is expensive and we should devise techniques to multiplex many signals so that they can share the available bandwidth. We also have to provide each traffic type with the required Quality of Service (QoS).

Trend 4: Data Volume is Greater than Voice
The volume of data traffic in today's networks is far more than voice. With the exponential growth in data and traffic, telecommunications service providers are suddenly finding that their real future is in transporting data. However, there are major differences in the way data and voice networks are designed and maintained. The dynamic content-driven surge of the WWW is taking data telecommunication systems into the next millennium beyond the previous benchmark set by the ubiquitous voice networks encircle our planet. Clearly, there is a need to change the telecommunications systems' design and adopt new technologies and practices that are significantly different from the past. The carriers have to choose between going to the new business or keeping old business. These data telecommunications networks will be very different from the past voice oriented telecom networks.

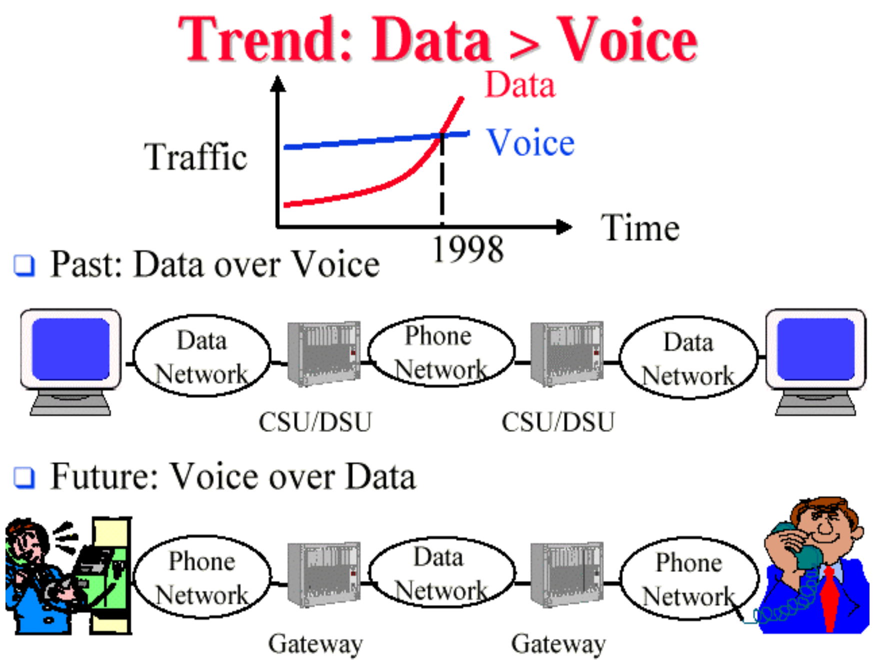

Figure 3: Current and past relation between volume of data and voice on the Internet [11, 15].

Trend 5: Increase Demand on Mobile Multimedia Services
The cellular networks providers and operators are going ahead to develop the third generation (3G) cellular networks and beyond (4^{th} generation systems). Wideband code division multiplexing access (W-CDMA) has been chosen as the technology to be used on air interface. There are challenges facing the development of the 3G wireless systems, however, it is expected that either new technologies can be used to implement the 3G

concept or go to a completely new system called 4th generation systems (4G). It is expected that ATM will be used for radio access network (RAN) transport due to ubiquitous nature. For heterogeneous traffic types, QoS guarantees must be established. However, the dominance of IP, owing to the success of the Internet, has paved the way for extensive studies on using IP as a general transport protocol in 3G cellular networks. Cellular operators are expecting an explosive growth on Internet traffic in mobile networks favoring an IP-based transport architecture for future wireless networks. The new version of IP, IPv6, has features to support QoS [15-16].

Mobile telephony is the dominant application in wireless networks today, and it is expected to remain so for several years. Multimedia applications in wireless networks are gaining popularity due to the success of the Internet. The 3G cellular networks will offer multimedia and packet switched services, Internet and Intranet access, entertainment and value-added services. The data rate that can be supported in 3G varies, depending on the service category. Mobile wide area service will be provided at 64 Kbps, slower pedestrian mode at 384 Kbps, and stationary office setting will be supported at 2 Mbps. The 2.5G has been deployed in several countries; however, the real 3G system is expected to be launched in the year 2003. ITU has recently approved a new ATM adaptation layer type 2 (AAL2) to transport compressed speech efficiently and within acceptable delay limits in ATM networks. AAL.2 seems to usher ATM into the cellular networks and could very well start a new era for integrated services in a wireless environment. When the work on the UMTS standards was started several years ago, ATM was thought to be the default transport technology in the 3G. However, during the last few years there has been a change in this view: the role of IP has gained more and more importance during the standardization phase. It is expected that most of the UMTS services, both in terms of number and volume, will be based on IP as a service platform [14-16].

III. Future of Telecommunications and Networks Systems.

Based on the past experience, the future network architecture is not clear. The most likely answer is something not even on the radar screen. In the LAN systems, Ethernet derivatives will be the likely winner. In the WAN systems, IP backbone will be a mix of packet over SONET and ATM depending on the traffic mix. Will ATM over xDSL become the future Internet access method of choice? Most integrated accesses and QoS-aware private and virtual private networks will likely use ATM. However, it is not always the quality of the technology that wins. The power of the mainstream has proved to affect technical decisions.

ATM services already are available worldwide and now moving out towards mobile and teleconferencing and telecommuting users via wireless ATM and xDSL technologies. The Internet must accommodate different classes of service for users willing to pay for different QoS. This must happen since someone must fund the tremendous growth rate of the Internet backbone. It is expected that IP and ATM will replace current N-ISDN and TDM-based voice network infrastructure. ATM may become the solution to offer different QoS to different applications over the Internet. It offers the best method for guaranteeing end-end QoS across WANs. Telecommunications systems will never be the same.

Voice services are traditionally telecommunications services. The entire network of twisted-pair transmission lines that make up a large portion of the international telephone network is based mainly on analog voice communication. The majority of Internet users these days use modems and voice grade lines to connect their computers to the Internet. Such a technique is satisfactory for text or fax; however, it is inefficient for multimedia applications due to the low speed. A two-way video call that provides VCR quality through data compression requires a 1.55 Mbps (T1 rate) transmission rate. Clearly, this is far in excess of the capabilities of traditional twisted pair telephone line unless new electronics techniques such as high bit rate digital subscriber line (HDSL) are deployed. High definition TV (HDTV) quality video requires a higher transmission rate in the range of 10Mbps. Clearly, such rates are not possible when analog techniques are used. There is an impressive progress in digital-based optoelectronics in terms of the increased capacity of fiber optic technology. Today, 2.5 Gbps commercial systems are becoming common. These can carry over 37,000 simultaneous voice calls on a single pair of fiber optic cables. It has been observed that the capacity of fiber optic systems has been doubled every two years. This is possible due to the use of dense wave division multiplexing (DWDM) technology.

Data communications equipments have been developed to handle bursty packet switching. The new generation of asynchronous transfer mode (ATM) and synchronous optical network (SONET) equipment is optimized to handle all types of service, including voice, video, image, data, and multimedia traffic. Using these technologies will enable interactive information systems so that full-motion video and high quality audio will be incorporated into networked applications as easily as text today. Such new services will be attractive to the degree that they will stimulate demands.

With the high speed transmission and ATM technology, the wide area networks, WANs, becomes an extension of the computer, freeing the processing, storage and retrieval functions from dependence on location. The new network systems will be more intelligent than current practice. Software packages could be distributed through the high speed networks instead of CD-ROMs. This means that education, training, medical, marketing, entertainment, and other multimedia applications could be delivered easily and by tens of thousands of program providers. The potential of worldwide communications system- based on digital technology is tremendous.

The winning approach in telecommunication technology is the scheme that gives an end-to-end future proof solution that ensures maximum utilization of bandwidth and the existing infrastructure, while providing for virtually unlimited expansion to accommodate future communications needs by either upgrading the existing facilities or expanding into new paradigms (platforms). The challenge to the designer is not only to provide the service, but to provide it in a cost-effective manner [11-16].

IV. Future of Computer Systems

Over the past 50 years, digital electronic computers have gone through five generations of development. Each generation has improved from the previous generation in both hardware and software technologies. A common feature of modern computers is parallelism, even within a single processor. The computer technology has progressed very rapidly in the last decade [1-3], [7-9], [17].

The concept of scalability has been reemphasized, which includes parallelism. A computer system, including its hardware and software resources, is called scalable if it can scale up (i.e. improve its resources) to accommodate ever-increasing performance and functionality demand and/or scale down (i.e. decrease its resources) to reduce cost. Keep in mind that scalability is not equivalent to being big! It involves the ability to scale down [18]. Future microprocessors will be designed with: (a) much denser and bigger microchip, (b) lower CPI (Cycle Per Instruction), (c) increased power consumption, (d) Higher ILP (Instruction Level Parallelism), and (e) more sophisticated software support.

In 1994, the Semiconductor Industry Association (SIA) has predicted that by year 2010, 800 million-transistor CPU chips will be produced with thousands of pins, a 1000-bit bus, a clock rate over 2 GHz, and a power dissipation as high as 180 Watt. In the year 2000, Intel unveiled a processor that runs with a clock rate of 1.5 MHz! Billion-transistor microprocessors will appear in the next decade. Albert Yu, head of Intel microprocessor products, has predicted the future of microprocessor in late 1996. The prediction suggested in 10 years, the transistor count could jump to 350 million in year 2006. The square die size will increase from 0.7 in to 1.4 inch on each side. His prediction of clock rate for the year 2000 was really conservative as in the year 2000.

Martzke has indicated that the most important physical limit is the fact that on-chip wires are becoming much slower than logic gates as the line width and on-chip devices shrink dramatically in the future. A single global clock may not be able to drive a billion transistors over the entire microchip. Although reduced feature size is good news, wire scaling and clock skewing may severely sabotage the performance gains. Only 16% of the die will be reachable within a single clock cycle in a billion-transistor processor. Another limit may be imposed by excessive heat released from a giant CPU chip. This leads to cooling and packaging problems. All of these physical problems have to be tackled in the years ahead of us.

There are two basic techniques to improve processor performance [18]:

1. Exploit ILP (Instruction Level Parallelism): Superscalar processors are designed to exploit ILP in user program. Only independent instructions can be executed in parallel without causing a wait state. ILP amount varies from one program to another. In ordinary program traces this ranges from 2 to 5. The measure can be higher such as 500 or higher. This is called Superscalar. Single-issue RISC processors were gradually replaced by the introduction of 2-issue processors such as Digital 21064, Pentium, MicroSPARC 2, M68060 and others.

2. Increase the clock rate by subdividing the instruction pipeline into simpler stages. This is called Super pipelining. Embedded Microprocessors use this technique. These chips have enabled digital consumer electronics. They are mainly for DSP, media processing, and microcontroller applications. Examples on embedded processors include Hitachi SH-7604, Digital SA-110, IBM PPC 403GA, Motorola 68EC040, and Intel 960HT.

There are two recent initiatives in the USA aimed at developing high performance computer systems to meet the grand challenging applications of the 21st century. These are [7-8], [16]:

1. The Petaflop Project: It aims at a long-term goal to achieve a speed of Pflop/s (10^{15} flops/s). Recent studies revealed that using commodity off-the-shelf (COTS) components could be built by the year 2015 at a cost of 1 Billion US dollars.

2. The ASCI Program: In 1994, the U.S. DoE launched the Accelerated Strategic Computing Initiative, ASCI, program, which is a 10 year $ 1-billion program aimed at building a Tflop/s HPCs to simulate nuclear weapon stockpile, biotechnology, weather prediction, aircraft/ automobile design, environment protection, etc. Intel, IBM and SGI won contracts to work on this project.

V. ICT Security

Securing access to communications and IT systems has become recently an important issue due to increased dependence of individuals and organizations in computer systems and networks to store and communicate data in them. The risk of accessing a computer system or network ranges from inconvenience to catastrophe. The main security services of any security systems are [10], [19], [20]:

1. <u>Confidentiality:</u> To ensure that information in a computer system and transmitted information are accessible only by authorized parties.
2. <u>Authentication:</u> To ensure that the origin of a message or electronic document is correctly identical, with an assurance that the identity is not false. Also, sometimes it refers to both verification of identity and the various functions listed under integrity.
3. <u>Integrity:</u> To ensure that only authorized parties are able to modify computer assets and transmitted information.
4. <u>Nonrepudiation:</u> Requires that neither the sender nor the receiver of a message be able to deny the transmission.
5. <u>Access Control:</u> Requires that access to information resources may be controlled by or for the target system.
6. <u>Availability:</u> Requires that computer system assets be available to authorized parties when needed.

Many countries started some initiatives to secure their information and communication infrastructure from hackers, and enemies. The increased use of e-commerce and e-government services has prompted many IT firms to establish new technology line in anti-virus Development.

Many new techniques that rely on biological features (biometric features) are being used to secure access to communication and IT systems. Among these are the Voice, Fingerprints, Face, Iris, Ear (INS in USA specifically requests photographs of individuals with clearly visible right ear.), Keystroke Dynamics Devised by Obaidat and Sadoun[10, 19], and DNA.

VI. Recommendations to Bridge the Digital Divide in the MENA Region

Information, Communications and Internet technologies are transforming the world's economy and making our world a global village. These technologies have impacted all aspects of our life. The use of these technologies by public agencies, businesses, and private citizens worldwide has grown rapidly during the last decade. Governments and organizations that fully utilize these technologies will not only improve the quality of service and cut the cost of services; they will create information societies in which the rapid economic growth and employment are expected. However, access to these technologies remains extremely uneven. This disparity — the so-called "information or digital divide" — is mainly a reflection of deeper social and economic inequalities both between and within countries. It is expected that the market forces, while the primary driver for ICT deployment, will not alone bridge this gap in ICT.

ICTs are powerful means to promote economic growth and social development at the same time that they render many traditional economic approaches less viable. It is vital that developing countries respond quickly to this new paradigm, otherwise, they will not be in a position to participate in the global economy and improve the standards of living of their citizens. Not just this, the digital gap among their own citizens will become wider. It is true that the risks are great, but so are the rewards. ICTs have the potential to create earnings opportunities and jobs, improve delivery and access to health and education, facilitate information sharing and knowledge creation, and increase the transparency, accountability and effectiveness of government, business and NGOs. This will establish a healthy environment for development and progress. By making ICT an integral and essential component of development, developing countries and their partners can more effectively address economic and social divides. In order to be successful, these countries need to develop comprehensive plans and strategies for ICT. They also need to establish reliable ICT physical infrastructures to meet the expected demands on bandwidth and speeds of communications by the many applications and services to be provided under the new paradigm. They also need to adopt measures to ensure equitable access and widespread capacity to make use of ICT. These ICT and e-Development strategies need to take into account concerns including basic logistics, access and use, enabling environments, human capacity, national and global governance issues, and new market and policies for inclusive growth, among others [21].

In most developing countries, the basic utility services are in adequate and unreliable. Not just that the citizen in these countries waste on the average 1-2 working days per month in order to pay for these services due to poor logistics. Basic services such as mail delivery, and streets numbering do not exist and about 25% of the postal mail is not delivered to the addresses. Despite the fact that the majority of developing countries already have the basic communications infrastructure to connect to the global information network, affordable and equitable access is still a crucial issue. In a recent estimate, it was found that less than 15% of the total number of users of the Internet and ICT live in developing countries. The situation is worse in the Least Developed countries, LDC. The cost of Internet connection in almost all developing countries is higher than that in developed countries despite the fact that the average income in these countries is far below that in developed countries. Not just that, the labor cost in developing countries is cheaper that in developed countries.

It is important to establish legislation for e-business as well as a national digital certification agency. Most developing countries do not have legal frameworks and institutional capacities to foster widespread adoption of IT or to attract the relevant national and international investment for infrastructure, enterprise, services and capacity development. Only 30% of developing nations have started the process of planning and creating such an enabling environment.

Training of people, especially skilled people on ICT technologies is essential. It should start from the elementary school up to the college level. Developing countries need to address the capacity gap to secure not only a reasonable number of technically qualified individuals, but also to acquire the expertise to assess, design and implement national ICT for development strategies. Possible strategies include the establishment of research parks in ICT that includes in addition to the universities, facilities for companies to conduct research and development with the collaboration of skilled faculty members and graduate students.

Few developing countries participate in ongoing worldwide dialogues on ICT issues. Critical issues that impact their future in the global economy — such as domain names, security, intellectual property, e-commerce and e-government legislation and standards — are defined and decided upon without their knowledge, participation, or involvement. Furthermore, the majority of developing countries lack the human and institutional capacity to rapidly adapt and absorb new policy frameworks related to these issues and to make use of ICT to enhance citizens' and private organizations' participation in the development processes.

According to recent statistics, the real value of traditional exports from developing countries has been declining. Clearly, these countries have to evaluate the impact of ICT on existing sectors; and identify the potential for ICT to create new job opportunities. Moreover, they have to benefit from the local cheap labor to attract external investors in ICT.

It is important that governments in developing countries give incentives to local telecom and Internet Service Providers (ISPs) to charge less for rural and remote areas. This is supposed to help bridge the digital divide within these countries. New programs in IT related fields such as e-commerce, computer science, computer system engineering, telecommunications and computer networking, computer and network security, computer communications, network information systems, among others, should be established in order to produce skilled graduates in these disciplines. Continuing educations in IT and Internet related courses should be conducted by local national universities in order to reduce the IT and Internet illiteracy in these countries. Free Internet centers should be established in various suburbs of cities and towns as well as villages that could enable citizens, especially disadvantaged individuals and communities, to be literate in Internet.

It is essential to install communications and information infrastructures capable of supporting the creation and sharing of information and knowledge as well as support research and development in information and communications technologies.

VII. Conclusions

To conclude, information, communications and Internet technologies are changing the global economy and are impacting all aspects of our life. Progress in these technologies is moving rapidly with amazing breakthroughs. Such technologies are creating new economy, new social life, new classrooms and universities, new telecom and networking systems, as well as new issues. The 21st century will witness massive explosive growth in traffic of all types in the global Internet(s). New NTERNET(S) will be launched to cope with ever increasing demand on bandwidth and speed. The increasing bandwidth demand of new applications such as distributed database systems, video-on-demand will move optical networks to the mainstream. A new generation of optical networks is coming very soon. It is characterized by multi-gigabit data rates, very high bandwidth, low error bit rates, availability, and maintainability, and better security characteristics. The consequences of access to ICT systems by unauthorized users range from inconvenience to massive loss of money or to catastrophe. This means that securing access to these systems is becoming a vital issue in the 21st century. There is a multi-billion dollar industry in this field. Many governments worldwide have started national programs for research and development in IT and Networks security. Biometrics-based authentication techniques have a great potential to improve computer and network systems security due to their high accuracy. Future computing platforms will be open and integrated. We will have integrated open computing systems that have traditional digital electronic computers, Neurocomputers, and Optical Computers. Despite the outstanding progress in microprocessor technology, we still need massively parallel processing computers that enable us to tackle grand challenging problems such as distributed and parallel simulations, oil exploration, environment protection, scientific computing, and weather forecasting, among others.

We are behind in software technology and although we have over 2500 programming languages, few of them are efficient and almost all of them are platform dependent. We need massive investment and efforts in software development, testing, verification, benchmarking, and training. Parallel programming languages are a few and inefficient. There is no point in developing a new MPP if the parallel programming languages are inefficient and difficult to use. New IT related disciplines, applications and academic programs are proliferating. Wireless communications and mobile computing will play an important role in the 21st century. There is an ongoing immense growth, innovation, and applications in this field [11], [21].

Developing countries have to work hard to catch with ICT wagon. New strategies and plans have to be put in place to bridge the digital divide between the developing countries and developed countries. Developing countries should install ICT national infrastructures that are reliable and fast in order to attract investment in this field and to facilitate there transfer to the digital world. Bridging the digital divide within the developing countries is essential in order to have equal opportunities within each country. Finally, it is going to be ICT-based Century with great achievements, applications, surprises, and impacts!

References

[1] M. S. Obaidat, " Telecommunication Systems for the New Millennium," International Journal of Communication Systems, Wiley, Vol. 12, Nos. 5 & 6, pp. 321-324, September-Dec., 1999.

[2] M. S. Obaidat, "Performance Evaluation of Telecommunication Systems: Models, Issues, and Applications," Computer Communications Journal, Elsevier, Vol. 24, No. 9, pp. 790-797, May 2001.

[3] M. S. Obaidat, G. I. Papadimitriou, and A. S. Pomportsis, "An Efficient Adaptive Bus Arbitration Scheme for Scalable Shared-Medium ATM Switches," Computer Communications Journal, Elsevier, Vol. 24, No. 9, pp. 790-797, May 2001.

[4] G. I. Papadimitriou, M. S. Obaidat and A. S. Pomportsis, "Advances in Optical Networking," International Journal of Communication Systems, Wiley, Vol. 15, Nos. 2-3, pp. 101-114, March/April, 2002.

[5] M. S. Obaidat, Z. Al-Awwami, and M. Al-Mulhem, "An Efficient Injection Limitation Scheme for Fully Adaptive Routing in Wormhole Networks," accepted in the Computer Communication Journal, Elsevier, 2002 (in press).

[6] M. S. Obaidat, "ATM Systems and Networks: Basics, Issues, and Performance Modeling and Simulation," accepted in the Transactions of the Society for Modeling and Simulation International, SCS, 2002 (in press).

[7] M. S. Obaidat, "Performance Evaluation of High Performance Computing/Computers," Journal of Computer and Elec. Engr., Elsevier, Vol. 26, N0. 3-4, pp. 181-185, May/July 2000.

[8] M. S. Obaidat, "Performance Evaluation of Computer and Telecommunications Systems," SIMULATION Journal, SCS, Vol. 72, N0. 5, pp. 295-303, May 1999.

[9] M. S. Obaidat and H. Khalid, "Estimating Neural Networks-Based Algorithm for Adaptive Cache Replacement," IEEE Trans. on Systems, Man and Cybernetics, Part B: Cybernetics, Vol. 28, No. 4, pp. 602-611, August, 1998.

[10] M. S. Obaidat and B. Sadoun, "Verification of Computer Users Using

Keystroke Dynamics," IEEE Trans. on Systems, Man, and Cybernetics, Part B, Vol. 27, No. 2, pp. 261-269, April 1997.

[11] M. S. Obaidat, "Information and Telecommunications Technologies Going into the 21st Century," Keynote speech, 2000 International Arab Conference on Information Technology, Zarka University, Zarka, Jordan, November 2002.

[12] W. Stallings, "High-Speed Networks: Performance and Quality of Service," Prentice-Hall, 2002.

[13] W. Stallings, "Wireless Communications and Networks," Prentice-Hall, 2002.

[14] S. Kalyanaraman, R. Jain, S.Fahmy, R. Goyal and S.C.Kim, "Performance of TCP over ABR on ATM backbone and with various VBR traffic patterns," IEEE International Conference on Communications (ICC'97), Montreal, June 1997.

[15] Raj Jain, "Recent Trends in Networking Including ATM and Its Traffic Management and QoS," Keynote Speech, International Conference on High Performance Computing HiPC'98, Chennai (Madras), India, December 19, 1998.

[16] P. Nicopolitidis, M. S. Obaidat and G. I. Papadimitriou, "Wireless Networks," John Wiley & Sons, August 2002 (in press).

[17] W. Stallings, "Computer Organization and Architecture," Prentice-Hall, 2002.

[18] Kai Hwang and Zhiwei Xu, "Scalable Parallel Computing: Technology, Architecture and Programming," McGraw-Hill, 1998.

[19] M. S. Obaidat, and B. Sadoun, "Keystroke Dynamics Based Identification," in Biometrics: Personal Identification in Networked Society, Anil Jain et al (Editors), pp. 213-229, Kluwer, MA, 1999.

[20] W. Stallings, "Cryptography and Network Security: Principles and Practice," Prentice-Hall, 1999.

[21] UNDP Report on UNDP Thematic, Trust Fund: "Information and Communication Technology for Development," WWW.UNDP.org.

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Professor Mohammad S. Obaidat is an internationally well-known academic/ researcher/ scientist. He received his Ph.D. and M. S. degrees in Computer Engineering with a minor in Computer Science from the Ohio State University, Columbus, Ohio, and his B.S. in EE from Aleppo University. Dr. Obaidat is currently a tenured full Professor of Computer Science at Monmouth University, NJ, USA. Among his previous positions are Chair of the Department of Computer Science and Director of the Graduate Program at Monmouth University and a faculty member at the City University of New York. He has received extensive research funding and has published over two hundred and twenty (220) refereed technical articles in refereed scholarly journals and proceedings of refereed international conferences. He is the co-author of the book entitled, “Wireless Networks” to be published by Wily in August 2002. Professor Obaidat has served as a consultant for several corporations worldwide. Mohammad is the chief editor of the International Journal of Communication Systems published by John Wiley. He is also a technical Editor of Simulation: Transactions of the Society for Modeling and Simulations (SCS) International-Part B. Obaidat is an associate editor/ editorial board member of seven other refereed scholarly journals including three IEEE Transactions, Elsevier Computer Communications Journal, Kluwer Journal of Supercomputing, Elsevier Journal of Computers and EE. He has guest edited 4 special issues of the SIMULATION Journal. He also guest edited a special issue (SI) of IEEE Transactions on Systems, Man and Cybernetics, SMC, on Neural Network Applications. He also guest edited SI’s for the Computer Communications Journal, Journal of C & EE. Currently, he is guest editing special issues for the Transactions of the Society for Computer Simulation-Part B, Elsevier Computer Communications Journal, IEEE Transactions on Systems, Man and Cybernetics. Obaidat has served as the steering committee chair and the program chair of the 1995 IEEE Int'l Conference on Electronics, Circuits and Systems, ICECS’95, and as the program chair of the 1996 IEEE International Phoenix Conference on Computers and Communications, IPCCC'96. He served as the Vice General Chair of the 1997 IEEE Int'l Performance, Computing and Communications Conference and the General and Program Chair of the 1997 SCS Summer Computer Simulation Conference. He also served as the General Chair of SCSC’98 and SCSC’99. He also served as Vice Program Chair for the 1997 IEEE International Conference on Computer Communications and Networks, IC3N'97. Dr. Obaidat served as the General Co-Chair of the 1998 IEEE International Performance, Computing and Communications Conference. He is the founder of the SCS International Symposium on Performance Evaluation of Computer and Telecommunication Systems, SPECTS and has served as the General Chair of SPECTS’98, SPECTS’99, SPECTS’01. Obaidat is the General Chair of SPECTS’2002 and the Steering Committee Chair of SCSC’2001 and SCSC2002. He is the Vice Program Chair of the 2001 Intl. Conference on Parallel Processing, ICPP-01. He has served on the program, advisory, organizing and steering committees of numerous international conferences. Obaidat has received a recognition certificate from IEEE. Between 1994-1997, Obaidat has served as distinguished speaker/visitor of IEEE Computer Society. Since 1995 he has been serving as an ACM distinguished Lecturer. Between 1996-1999, Dr. Obaidat served as an IEEE/ACM program evaluator of the Computing Sciences Accreditation Board/Commission, CSAB/CSAC. Obaidat is the founder and first Chairman of SCS Technical Chapter (Committee) on PECTS (Performance Evaluation of Computer and Telecommunication Systems). He is a member of the board of directors of the Society for Computer Simulation International. He has been invited to lecture and give keynote speeches worldwide. His research interests are: performance evaluation of computer systems, algorithms and networks, telecommunications and Networking systems, wireless communications and networks, high performance and parallel computing/computers, applied neural networks and pattern recognition, computer Security, and speech processing. Recently, Prof. Obaidat has been awarded a Nokia Research Fellowship. Professor Obaidat has been elected to be a Fellow of the Society for Modeling and Simulation International (Formerly, the Society for Computer Simulation International, SCS). Prof. Obaidat is a senior member of IEEE and a Voting Member of ACM .