
Networkcentric healthcare operations: the telecommunications structure

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Abstract: Healthcare globally is failing to meet its objectives of delivering appropriate medical attention to patients. We suggest that by adopting a networkcentric approach healthcare operations and delivery will be dramatically enhanced with the ultimate beneficiary being the patient. Underlying the networkcentric doctrine of healthcare is the use of IC2T. As discussed in the paper, all the essential network and telecommunication components already exist. We must now focus on how to combine them so that network centric healthcare can in fact become a reality.

Keywords: healthcare management; healthcare operations; global healthcare; e-health networkcentric; telecommunications; IC2T; wireless communications internet.

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1 Introduction: the world of healthcare

During his State of the Union Address in January 2004, President George Bush affirmed the intention of the government to emphasise the role of technology in the administration and delivery of healthcare in the USA (Bush, 2004). Similar sentiments have been voiced by European leaders (The Oslo Declaration on Health, Dignity and Human Rights, 2003; Global Medical Forum Foundation, 2005) and the World Health Organization (WHO).¹⁻² Both European and US authorities define their initiatives primarily in terms of medical information technology centering on Computerised Patient Record (CPR) or, in more acceptable parlance, the Health Electronic Record (HER) (Brailer and Terasawa, 2003). WHO's platform statement¹ speaks of 'health telematics policy', an all-inclusive term that incorporates not only HER but essentially all healthcare services provided at a distance and based on the use of Information, Computer and Communications Technologies (IC2T). While implementation of these concepts is preeminently realistic in the context of EU and the USA, the WHO plan appears, for many reasons, a combination of a list of good ideas and a delineation of significant obstacles that make the good ideas seem almost futuristic.

The reality of the world being divided into two entities – the functioning core and the nonintegrating gap (Gronlund, 2002) – is not a new one, and the concept of the rapidly

advancing Western economies existing in the atmosphere of the progressively increasing discomfort created by the plight of the Less Developed Countries (LDCs) has attained a cliché-like reality. The wide range of social and economic disintegration represented by the LCDs and their contrast to the Western world is mirrored with equally stark clarity in the arena of healthcare. Even if per capita expenditure on healthcare is not the best indicator of money spent on actual maintenance of health (average expenditure in the EU is about 50% of the US amount, yet the Europeans appear to receive equal if not better quality of care than the citizens of the USA) (Barnett, 2004; World Health Organization Report, 2000), in the USA nearly \$4900 was spent per capita in 2001. Its closest neighbour to the south – Mexico – spent only \$370, while Mali could afford only \$12 (World Health Organization Report, 2000). The significance becomes striking when one relates these numbers to the mortality rates caused by diseases common to the developed and either developing or underdeveloped nations. India and South Africa (countries with rapidly developing economies and with ‘globally average’ healthcare expenditure, see World Health Organization Report, 2004) have cardiovascular mortality rates seen in the USA 30 years ago.³ One reaches the inescapable conclusion that increasing demand for healthcare is accompanied, paradoxically, by proportionately fewer resources available to provide such care (Leeder *et al.*, 2004). It becomes equally obvious that while energetic use of information technology in healthcare will reduce costs of administration and delivery and may lead to major improvements in quality (through, for example, reduction of medical errors) in the Western world, similar advantages may not be obtained as readily among the less developed countries, where the expenditure needs to be drastically increased in order to reach even minimally acceptable access and quality of the most traditional forms of healthcare delivery.

In the current debates on healthcare economy, it is too often forgotten that the level of health among the populations of LCDs affects not only the future of business and the regional political stability, but also global security (Hart, 1995; World Economic Forum, 2002). Many of the diseases currently considered to be major candidates for use in acts of bioterrorism (such as viral haemorrhagic fevers) are endemic to the countries lying within the ‘non-integrating gap’ of Barnett (Gronlund, 2002). The prevalence of poverty, politico-economic instability and concomitant poor healthcare leads to the feelings of outrage among the affected populations, who then serve as easy prey for demagogues, resulting in international violence (regional conflicts) and global terrorism (Gronlund, 2002). It is obvious that the need to pay attention to the healthcare level and quality offered to the increasingly disenfranchised and turbulent populations living within the ‘gap’ is not, as sometimes perceived, the charitable duty of Western philanthropy. Instead, it is the essential task of self-preservation that needs to be undertaken by the governments of the affluent nations which, by providing the vital ingredients necessary for the improvement of local economies, will allow conversion of hitherto ‘rogue’ states into functional democracies (Gronlund, 2002). As much in business as in healthcare, the development of IC2T infrastructure in the less developed world and both development of operational efficiency and further vigorous expansion of the existing infrastructure in the developing countries appear to provide the best chance of reaching healthcare parity between ‘haves’ and ‘have-nots’. Without technology as the major restructuring tool, the financial outlay needed for the recreation in the underdeveloped countries of the traditional healthcare environment that the West is about to abandon (*e.g.*, the network of clinics, typical hospitals, enhanced advanced provider density, multiple training facilities) is simply unsustainable.

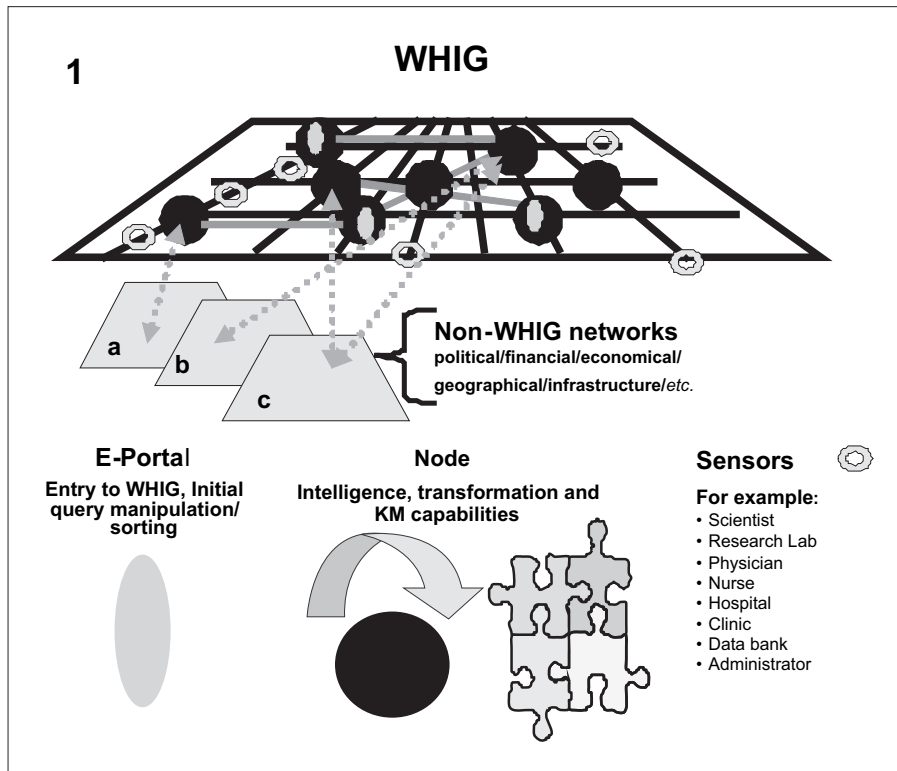
2 IC2T in healthcare operations

The effective conduct of healthcare operations is not only extremely expensive. It is also extremely complex, particularly when executed at the global scale. Most healthcare problems affecting the world have multiple roots involving social, economic, political, and even geographical factors, whose combination provides fertile grounds for the spread of illnesses, prevalence of trauma, enhanced mortality, *etc.* (Evans, 1993). As a remedy, it has been proposed that, instead of the currently practised concentration on a specific devastating illness that captures public attention, such as HIV/AIDS, a comprehensive ‘systems approach’ offers the best approach to the solution to the causative factors of global healthcare problems (Evans, 1993). Presently, the governments and political bodies of both the European Union and the USA are beginning to view the ‘systems approach’ as the only viable option (Akhtar, 1991; European Institute of Medicine, 2003; National Coalition on Healthcare, 2004).

It has been hoped that vigorous use of IC2T will, similarly to some forms of business operations, obviate the growing chaos of global healthcare. While IC2T changed many aspects of medicine, the explosive growth of worldwide healthcare costs indicates that a mere introduction of advanced technology does not solve the problem (Kyprianou, 2005; von Lubitz and Wickramasinghe, 2005c–d). The quest for financial rewards provided by the lucrative healthcare markets of the Western world led to a plethora of dissonant healthcare platforms (*e.g.*, electronic health records) that operate well within circumscribed (regional) networks but fail to provide a unified national or international service (Onen, 2004; Olutimayin, 2002). In addition, there is a striking lack of standards that would permit seamless interaction or even fusion of nonhealthcare (*e.g.*, economy or local politics) and healthcare knowledge creation and management resources. Thus, despite the massive amount of information that is available to healthcare providers and administrators, despite the availability of technologies that, theoretically at least, should act as facilitators and disseminators, the practical side of access to, and the use and administration of, healthcare are characterised by increasing disparity, cost and burgeoning chaos (Banjeri, 2004).

Our previous publications (Kyprianou, 2005; Larson, 2004; von Lubitz and Wickramasinghe, 2005c) discussed the general principles and applicability of the military networkcentric operations concept (Cebrowski and Garstka, 1998) and its adaptation to modern worldwide healthcare activities. The proposed networkcentric healthcare operations are conducted using the World Healthcare Information Grid (WHIG) – a multidimensional communications network connecting all relevant information acquisition entities (sensors) with information processing, manipulating and disseminating organisations (nodes.) The nodes also serve as knowledge gathering, transforming, generating and disseminating centres (Figure 1).

Figure 1 Schematic diagram of a WHIG segment. Sensors feed raw data/information into the network through network-distributed portals. Likewise, data, information and knowledge queries enter through portals as well. The latter provide entry-level security screening and sorting/routing. Subsequent manipulation, classification and transformation into information/pertinent knowledge is executed by interconnected nodes. Whenever required, each node can access information/knowledge existing within non-WHIG networks and databases and compare/merge the contents with the contents existing within the WHIG. While portals are associated with the nodes, implementation of ASP philosophy allows for reaching the portal from anywhere within the WHIG.



At the highest level of complexity, healthcare activities are characterised by multidirectional and unrestricted flow of multispectral data derived not only from research/clinical/administrative sources, but also from fields that may appear to be almost entirely unrelated – economy, politics, social structure, *etc.* (Kyprianou, 2005). At the interdisciplinary level, the data exist as highly incompatible entities, access to which is frequently virtually impossible. In networkcentric operations, raw data, information and node-generated knowledge exist in fully compatible formats based on standards that allow automated meshing, manipulation and re-configuration. Essentially, networkcentric healthcare operations are based on the principles of high-order network computing, with the WHIG serving as a rapid distribution system, and the nodes as the sophisticated processing centres, whose task is to act as integrated data/information/knowledge generating sites and DSS/ESS platforms providing high level, query-sensitive network-wide outputs. The nodes are also capable of extracting and analysing data and information from healthcare-relevant sensors and electronic data

sources (*e.g.*, financial, political, military, geological, law enforcement, infrastructure level), meshing complex inputs into knowledge blocks relevant to both specific and general healthcare issues. The incorporation of external information in healthcare operations is not only necessary, but often critical, element that will ultimately determine the success of either planned or conducted activities (von Lubitz and Wickramasinghe, 2005a–b; Randolph and Cogdell, 1996). The complications either resulting from the failure to include elements external to the essential healthcare activities or consequent to the exclusion caused by either sheer ignorance or incompatibility of information/knowledge resource platforms have been amply demonstrated on several occasions (Baker, 1989; Griekspoor and Collins, 2001).

The theoretical foundations for the activities characterised by a broad range of multidisciplinary (multispectral) inputs have been synthesised by Boyd as the OODA Loop (Byman *et al.*, 2000; see also Kyprianou, 2005; Larson, 2004; von Lubitz and Wickramasinghe, 2005a–c), whose practical applications ramify from military activities to global financial/banking operations, lean manufacturing, just-in-time supply chains, medical training, *etc.* The rules described in Boyd's (OODA) Loop apply particularly well to major, international healthcare programmes that are often executed in highly fluid, ultracomplex environments that demand not only rapid, reliable sampling of the environment (data/information collection) from a broad variety of sources but also a very high degree of automation at the subsequent levels (manipulation and classification into larger information/germane knowledge entities). Contrary to the prevalent platformcentric operations, networkcentricity allows a vast increase in sampling speed, range and data manipulation speed. Consequently, decision-supporting outputs of the network are faster, more situation/operational environment-relevant and, most importantly, allow a robustly elevated rate of stimulus-response cycle. Moreover, by increasing reaction relevance and speed, networkcentric operations facilitate goal-oriented manipulation of the operational environment and also increase both the level (accuracy) and predictive range of responses to environment-induced pressures. Most importantly, many of such analyses can be performed using ASP and remote client/proximal server principles, which alleviate infrastructure-poor regions from the need for significant allocation of resources on advanced information processing technologies. However, in order for such interactions to happen, a well-integrated international system of multitype telecommunications must be in place. While the development of such an umbrella system can be conducted with the greatest ease among the Western countries, it is far more complex in the less developed world. The task is, however, not insurmountable, and the frequently raised arguments of prohibitive costs or nonexistent knowledge support at the local level may not be entirely true.

3 IC2T in networkcentricity

3.1 Driving technological forces in the IC2T development

The occurrence of the IC2T sector can be considered a result of the evolution and convergence of many industries, in particular, the information, computers, telecommunications, media and entertainment. Considering the three basic elements of IC2T – networks, services and terminal equipment – we can define the main factors that determine the evolution of these elements and the main trends that fully characterise the

process of the IC2T sector's evolution. The achievements in the following key areas are the most important driving technological forces in the evolution of IC2T basic elements:

- microelectronics
- photonic technologies.

Microelectronics is the first major enabler in the IC2T industry. We find microprocessors and memory chips in almost every product on the market today. In accordance with Moore's law, formulated in 1965 (Boyd, 1987), the number of transistors that could be integrated per square inch and microprocessor performance have doubled every 18 months, with cost decreasing by 50% since Integrated Circuits (IC) were invented. In 1975, the figure was revised to a doubling time of 24 months and Moore's law was absolutely followed by the IC industry, at least between 1975 and 1990. From then on to the 2000s, the trend has lowered to a doubling time of 30 months. The current doubling-time target is 36 months (Desurvire, 2004a).

Thus, two factors are considered to be the key driving forces: the increase in computer performance and the decrease in the cost of devices. This makes it much easier to use computer technology as the IC2T platform. Wide application of computers has become one of the leading factors influencing the parameters of information/communications systems and determining the growth of transmission and switching systems capacity and the availability of a greater range of services with a decrease in cost. What does it mean? For example, the modern cellular phone, equipped with a multimedia card, can store and play about 60 minutes of high-quality music. In a few years, similar devices will have the power to store and process several days of music or several hours of video, and it is possible to expect that its cost will be approximately the same.

In optical networking, or photonics, the development of system performance has been even faster than in microelectronics. The implementation of fiber optic systems in communications networks began in the mid-1970. The capacity of optical transmission systems has doubled every 10–12 months. The most impressive results in the growth of network capacity were achieved in transport networks, where the application of fiber optic cables and SDH systems allowed for providing a transmission speed of up to ten Gbit/s at the beginning of the 1990s. The further growth of transport network capacity has become possible with the application of DWDM technology, based on the principle of wavelength multiplexing of channels, and allowing to be reached bit rates of several hundreds of Gbit/s and tens Tbit/s through the single fiber. To understand the significance of these figures, we should remember, that the total world telephone traffic today does not exceed several Tbit/s.

New technologies nowadays provide for practically an exponential growth of network capacity, substantially increasing network capabilities and reducing the cost of information transmission. The necessity of the rapid growth of network capacity is due primarily to a boom in the growth of traffic, especially data. The great growth of traffic in communications networks is determined by a number of factors, among which the following should be mentioned: accelerated development of the internet and escalating applications of graphic and video information exchange.

3.2 *Main technological trends in IC2T*

The underlying (global) trends determining the IC2T development are the following:

- all penetrating digitalisation
- growth of the internet
- growth of mobile communications
- convergence of networks, services and terminal equipment.

The digitalisation of information, information processing tools and transport systems are the most powerful factors of progress in IC2T. The transition from analogue to digital format, which started in the 1960, makes it easier to accomplish processing, accumulation and transportation of information. Networks were traditionally designed and built for certain types of traffic, such as voice, data, text or video. Digital networks can be regarded as general-purpose networks, providing the transportation of any type of traffic.

Another main trend in the IC2T industry is the development of the internet. The internet is accelerating the convergence of the once separate worlds of information technology, telecommunications, media and entertainment. In the coming years, all information existing worldwide will be digitised. That means that all books, music, pictures, publications, and so on will be accessible via the internet. According to the latest internet statistics, the number of hosts connected to the net is increasing without any sign of receding (Tuomi, 2002; Downer and Mui, 1998). The explosive growth of the internet during last ten years (since the middle of the 1990s) is a direct result of progress on the software, microelectronics and development of high-efficiency communications systems, as well as of changes in telecommunications legislation and regulation. The growth of the internet is an example of the most rapid adoption of technology by a great number of consumers, as compared to other information technologies. The number of radio users in the USA had reached 50 million 38 years after it had been invented; PCs have become available to 50 million users 16 years after they had been invented. By contrast with these most successful information technologies, the number of internet users in the USA has reached 50 million only four years after the internet actually became a public network.

It is obvious that mobile communication is one of the most powerful trends in the IC2T industry. In 2002, the total number of world mobile users reached 1.2 billion and exceeded the number of fixed telephone users. Mobile communication is regarded today as an important motivating force in the developing regions of the world, where it can become an important alternative to fixed telephone networks. A constantly growing mobility will be maintained by mobile cellular systems of the third generation (3G), which should replace 2G networks (GSM standard). The 3G networks, which are presently being developed in the frame of UMTS projects, will operate in all continents and will provide the users with all possibilities of broadband services. Bandwidth growth, which is a typical characteristic in fixed networks, will be a necessary condition for the development of mobile systems in the near future.

The mobile revolution is more than a mobile phone only. The wide application of mobile systems and mobile services used, in the first turn, for data transmission will result in the development of such new forms of activities as telecommuting, which is work during trips. The mobility concept will play the key role in eliminating the

boundaries between home and office. The mobility concept is closely related to the personal communications concept. As mobility and personal communications are developing, the telephone number will be correlated with an individual user rather than with a geographical point or physical address. Digitalisation will accelerate the advancement of personal-communications-mobility ideas. In this case, the network will maintain intellectual properties, providing the possibility of determining the position of an individual user. After the introduction of General Mobile Personal Communications System (GMPCS) – a system of personal mobile communications based on satellite communications – the aim of providing communications in any point at any time will be achieved.

In recent years, the term ‘Convergence’, often used in describing evolutionary processes in different areas, had become a widely used term in the IC2T sector. In December 1997, in the Green Paper of the European Commission,⁴ the term ‘Convergence’ was defined as a possibility of various network platforms to provide practically the same set of services or unification of user’s devices, such as telephone, PC and TV set in the form of a single terminal. Today it is universally recognised that a convergence will be carried out on the internet platform.

These are the areas in telecommunications where convergence at present is significantly met. Today, most attention is paid to the convergence of voice and data networks. Another interesting instance of convergence is subsumed under the term Fixed/Mobile Convergence (FMC). The most important issue of FMC is the service convergence, meaning that users can have their services accessible and available as they are accustomed to at any network access – wired or wireless. One more example of convergence in IC2T is multimedia communications, where all types of traffic – voice, video, graphics and sound – may be used to convey information. The resulting consequences for the technical equipment are most visible in the terminal (PC or TV set), where facilities for the various communication modes have to be provided.

3.3 Telephone networks

The history of telephone networks began from the invention of Alexander Graham Bell. During more than 120 years, the telephone networks have evolved into a highly distributed, available and reliable system known as Public Switched Telephone Network (PSTN). PSTN today is the world’s collection of interconnected voice-oriented public telephone networks, both commercial and government owned.

PSTN is still growing and evolving. According to International Telecommunications Union (ITU) statistics, the total number of PSTN subscribers in the world in 2004 reached almost 1.2 billion. The main growth of PSTN comes from developing countries. The level of PSTN development is defined by telephone density – the number of telephone subscribers per 100 inhabitants of country, region or world. This parameter is strongly correlated with the level of economic development of the country. Telephone density in developed countries reaches 50% and more, whereas in countries with low income this parameter rarely exceeds 3%–5%. In such countries with huge populations and recent economic liberalisation, PSTN is likely to continue growing for the next decades.

The basic service that the telephone network provides to its users is two-way voice communication with a guarantee of Quality of Service (QoS). The required QoS is achieved by setting up a circuit between two endpoints. The major breakthroughs in PSTN have been the introduction of the digital switches, implementation of digital telephony, and use of fiber optics for communication. The invention of fiber optics led to the transmission revolution. Telephone companies decided to upgrade all long-distance trunks to fiber optics. In developed countries, this transition was essentially completed in the 1990s. Despite considerable progress, PSTN faces some important technical and social challenges, especially with multimedia communications. Multimedia communications is the simultaneous transmission of voice, data and video traffic. An example of multimedia communications is a videoconference between remote sites. The traditional telephone network is inadequate for multimedia traffic, first of all owing to a lack of capacity on the last mile (from local exchange to the home), as this segment of a network is based on twisted-pair copper cable. The best modems can provide no more than 56 kbit/s over a twisted-pair cable. Even if digital information is sent using Integrated Service Digital Network (ISDN) technology, only a bit rate of 128 kbit/s is available. To carry switched video, PSTN has to increase up to several Mbit/s the bit rates available on the last mile for mass users. Below we will consider the possible ways in which PSTN can evolve to meet similar challenges.

3.4 Internet

The internet, sometimes called simply ‘the Net’, is a worldwide system of computer networks – a network of networks in which users at any one computer can, if they have permission, get information from any other computer (and sometimes talk directly to users at other computers). The packet switching paradigm of the internet was developed by the Advanced Research Projects Agency (ARPA) of the US government in the second half of the 1960s. Packet switching is a technique whereby the information (voice or data) to be sent is broken up into packets, of at most a few Kbytes each, which are then routed by the network between different destinations based on the addressing data within each packet. The original aim was to create a network (originally named ARPANET) that would allow users of a research computer at one university to be able to ‘talk’ to research computers at other universities.

The internet, which started as a research project connecting three computers in September 1969, had grown by 2003 into a network, linking an estimated more than 700 million users. Today the internet connects tens and hundreds of millions of computers around the world, allowing them to exchange messages and to share resources. Users of the internet can exchange electronic mail, access files anywhere in a network, read and post to electronic bulletin boards, and publish information for other users. More recently, the possibility of transporting voice directly over internet, called Voice over IP or IP-telephony service, creates a new class of internet service allowing real-time voice conversations, different from that provided by traditional telephone networks.

Physically, the internet uses a portion of the total resources of the currently existing public telecommunication networks. Technically, what distinguishes the internet is its use of a set of protocols called Transmission Control Protocol/Internet Protocol (TCP/IP) that allows computers to exchange packets of information. The use of network resources is optimised as the resources are needed only during the handling of each packet.

For many internet users, electronic mail has practically replaced the postal service for short written transactions. Another popular application is a live conversation with other computer users, using Internet Relay Chat. The widest application of the internet today is the World Wide Web (often abbreviated WWW or called 'the web'). The web was invented in 1989 by Tim Berners-Lee, a British researcher at CERN's European Laboratory for Particle Physics in Switzerland. In the beginning, the web was used by CERN physicists to share experimental data and results, but since 1991 the web has been available to anyone using the internet. The outstanding feature of the web is hypertext, a method of instant cross-referencing. Hypertext allows users to move directly from a word or phrase highlighted on the screen to related information that may be stored on a different computer in another part of the world. The introduction of Tim Berners-Lee's hypertext system revolutionised the way the internet was used. Before the availability of easy-to-use web browsers, internet users had to deal with complex command-line interfaces. With the current special application programme, browsing using the internet is simply pointing and clicking. The most popular web browsers are Microsoft Internet Explorer and Netscape Navigator. Using the web, users have the possibility to access to millions of pages of information containing pictures, music and moving images, as well as text and data.

In developing countries, the internet has quickly emerged as one of the most useful means of communication, definitely far more useful than the telephone. In practice, the internet adds more services, many of which are especially appreciated in areas of extreme poverty where people are isolated from health, government, education and other facilities, making access to information crucial. In practical and economic terms, a document sent by e-mail costs significantly less than a fax, while international telephone calls made via the internet enable expatriates to be contacted at very low cost. Lastly, cable and satellite infrastructures can (or will in the future) bring isolated areas, like Africa, out of the wilderness and connect them to the world's high-speed communication backbones. So the challenge is how to develop universal access to make these infrastructures available to as many people as possible.

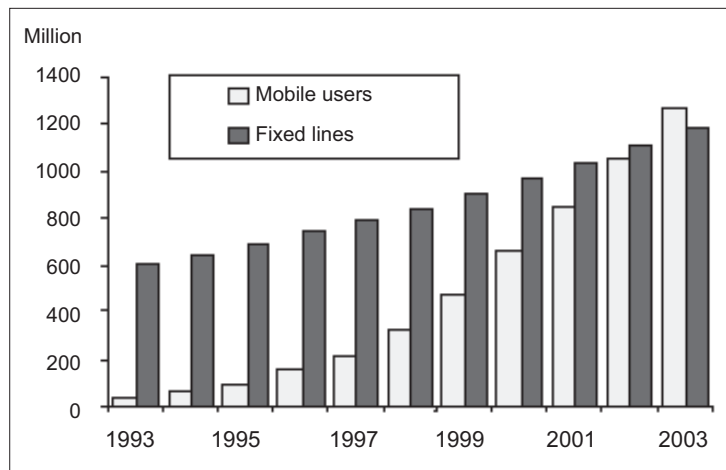
Today the internet is considered a major driving force in the IC2T industry. To prove the great possibilities of the internet, enthusiasts provide various data about the global character of the network, explosive growth in the number of users and websites, the endless number of new products, and new types of services and applications. However, critics point at the anarchical character of the network development, fast exhaust of network resources caused by new applications, low level of security and an absence of guaranteed QoS, which makes the internet technology poorly adaptable to the applications aimed at mass user. The explosive growth of the internet in the 1990s and its gradual transformation into a global network led to the situation where the features of classical IP (IP version 4, IPv4) became an obstacle to the network built-up and came into conflict with the scalability requirements. The development of new services related to the entertainment industry determined the emergence of information streams with new characteristics (first of all, multimedia traffic) and new requirements for QoS. The use of the internet for commercial aims leads to the necessity for special measures aimed at information security. To satisfy new requirements, the Internet Engineering Task Force (IETF) Committee – the main organisation on internet standardisation, has started active work (in the beginning of the 1990s) on expanding the possibilities of the IPv4, as well as on the creation of new mechanisms and protocols. A new version of IP (IPv6) and a number of QoS and security supporting mechanisms were developed during the last

several years. Based on new mechanisms, the internet is considered today a common technological platform for the creation of the so-called New Generation Network (NGN), which will converge all current separate networks – the fixed and mobile telephone networks and the classic internet.

3.5 Wireless communications

Wireless communications have become very pervasive. Wireless technologies today are used in local, metropolitan, and global networks. The number of mobile users has increased significantly in recent years (see Figure 2). According to ITU statistics, the number of subscribers of cellular communications in the world in 2004 reached 1.5 billion. It is expected that by the end 2005, the total number of mobile users in the world will be around two billion.

Figure 2 Grows of worldwide number of fixed lines and mobile users (million) in 1993 – 1999 with a forecast to 2003



Source: ITU world telecommunication indicators database and ITU forecasts in trends in telecommunications reform, 2000–2001: interconnection regulation

The first wireless public networks were made available in the beginning of the 1980s. These networks were analogue and supported the limited number of services with low quality. Traditionally, the first mobile public networks (named today the first-generation networks, 1G) were targeted only at voice and data communications occurring at low data rates. Compared to first-generation systems, 2G systems are based on digital multiple-access technologies, such as TDMA (Time Division Multiple Access) and CDMA (Code Division Multiple Access). Examples of second-generation systems are cellular GSM networks and wireless systems such as the Cordless Telephone (CT2), Personal Access Communications Systems (PACS) and Digital European Cordless Telephone (DECT). 2G networks are in current use around the world. While first-generation systems support primarily voice traffic, second-generation systems support voice, paging (SMS), data and fax services, and most 2G protocols offer different levels of encryption and security.

The main goal of 2G and 3G mobile networks' evolution is providing broadband features to satisfy the growing demand for access to multimedia services with Quality of Service (QoS) assurance. The transition from 2G to 2.5G mobile networks will begin with the introduction of General Packet Radio Service (GPRS). GPRS is a radio technology for GSM networks that adds packet-switching protocols, shorter setup time for internet connections, and the possibility of data transmission rates up to a hundred kbs. Another technology in 2.5G mobile networks heading towards third generation and personal multimedia environments is known as Enhanced Data rate for GSM Evolution (EDGE). It will allow GSM operators to use existing GSM radio bands to offer wireless multimedia IP-based services and applications at theoretical maximum speeds of 384 kbit/s. EDGE will let operators function without a 3G license and compete with 3G networks offering similar data services. Implementing EDGE will be relatively painless and will require relatively small changes to network hardware and software as it uses the same TDMA technology. GPRS and EDGE technologies are the most significant step toward 3G.

Third-generation mobile systems are faced with several challenging technical issues, such as the provision of seamless services across both wired and wireless networks (so-called universal mobility) and growing demand for access to multimedia services anytime, anywhere. In order to meet these customer needs, the European mobile industry is looking to define and develop the third generation of mobile technology – Universal Mobile Telecommunications System (UMTS). UMTS will provide the building blocks for service convergence between fixed networks and the 3G mobile networks to provide the user with the same high-quality multimedia services, both on his fixed and mobile terminal. UMTS will provide access to new and interactive services. It will offer mobile personalised communications to the mass market regardless of location, network or terminal used. The key characteristics of UMTS, derived from this vision, are:

- capacity for narrow and wideband services by high radio spectrum efficiency and bandwidth on demand
- data speed sufficient for multimedia service components characterised by bulk data transfer and interactivity
- quality of speech (comparable to the fixed network) and data services (guarantee low latency)
- service access comfort through a virtual home environment (same 'look and feel' of services and service manipulation anywhere), personalised services, improved user interface (*e.g.*, web-based), ubiquitous coverage for office, home and outdoors.

Standardised UMTS service capabilities will provide a platform that will enable the support of speech, video, multimedia, messaging, data, other teleservices, user applications and supplementary services. Service creation tools that combine these capabilities enable the market for services to be determined by users and service providers. Additionally, this concept reduces the time required to deploy new types of services in the network, giving operators the opportunity to compete on the service level.

3.6 Satellite communications

The sector of satellite communications is now more than 40 years old, dating from the launch of the first communications satellite, Telstar, in 1962. This satellite had the capacity of 12 telephone channels used for international calls over the Atlantic. Currently, there are hundreds of satellites in operation. They are used for such diverse purposes as weather forecasting, television broadcasting, amateur radio communications, fixed and mobile telephone communications, internet communications and Global Positioning. The progress in different areas of IC2T sectors – electronics, computers, radio, signal processing, antenna design, and, of course, space technologies – has set the basis for a great variety of modern satellite-based services, which can be categorised into the following general types:⁵

- fixed satellite services
- mobile satellite services
- broadcasting satellite services
- radio-navigation satellite services.

According to type of orbit, there are three types of satellite communications systems – Geostationary (GEO) systems, Low-Earth Orbit (LEO) systems, and Medium-Earth Orbit (MEO) systems. The GEO system orbits the earth directly over the equator, 22 300 miles up. A single geostationary satellite can ‘see’ approximately 40% of the earth’s surface. Three such satellites, spaced at equal intervals (120 angular degrees apart), can provide a coverage of the entire world. Initially, only low power was available in GEO satellites. This implied the use of large-size parabolic antennas of more than 10 m in diameter at the ground stations. A few years later, the available power in satellites increased and smaller ground station antennas of about 1 m in diameter could be used. Satellite systems based on small-diameter antennas are called Very Small Aperture Terminal (VSAT) and were used by home and business users. Examples of most representative modern GEO systems providing broadband services are Astrolink, Eutelsat, GE Star and Spaceway.

The nature of the satellite communications is good for such internet applications as web browsing and for downloading of files. Because of long latency compared with purely land-based systems, interactive applications such as online gaming, interactive TV and others are not compatible with GEO satellite networks. In a two-way geostationary-satellite internet connection, a transaction requires two round trips between the earth’s surface and satellite orbiting 22 300 miles above the equator. This occurs in addition to land-based data transfer between the earth station and the accessed internet sites. The delay in such a connection is theoretically about 0.3 second, and in practice is somewhat longer.

Better results from the delay’s point of view are provided by LEO and MEO systems. The LEO system employs a large fleet of satellites or ‘birds’ (not less than 50), each in a circular orbit at a constant altitude of a few hundred miles. The orbits take the satellites over, or nearly over, the geographic poles. The fleet is arranged in such a way that, from any point on the surface at any time, at least one satellite is on a line of sight. A well-designed LEO system makes it possible for anyone to access the internet via wireless from any point on the planet. Most representative LEO systems are Skybridge

(1997–1998) and Teledesic (1997–1998). Services offered by Skybridge and Teledesic include broadband internet, video-on-demand, video telephony, video conferencing and a whole array of novel IP-based applications, such as telecommuting, telemedicine and distance-learning. Lastly, the MEO system uses from 8 to 12 satellites, each in a circular orbit at a constant altitude of a few thousand miles. One of the most representative MEO systems is ICO, launched in 1995.

Satellite communications is considered today to be a very effective means of providing access to the IC2T sector's facilities. At the same time, it is necessary to take into account that satellite systems have certain restrictions connected, first of all, with delays. Besides, satellite systems are also prone to rain-fade (degradation during heavy precipitation) and occasional brief periods of solar interference in mid-March and late September, when the sun lines up with the satellite for a few minutes each day.

3.7 *Broadband access*

The term 'Access network' (or Subscriber Local Loop) defines a network's section between the subscriber's socket or, more generally, between the Network Termination and interface to the access node or to the local exchange. NT is a border dividing access network and user equipment. Nowadays the network's access segment can no longer exist as an isolated infrastructure. The construction of high-speed core networks, with a capacity of dozens and hundreds of Gbit/s, and the development of new services (high-speed data transmission, multimedia applications, *etc.*) resulted in the situation that access networks based on outdated principles and technologies became a 'bottleneck', limiting the subscriber's access to modern services.

One of the leading key factors to be taken into account when analysing the evolutionary processes in access networks is the high cost of access networks amounting to 50%–70% of the total cost of fixed networks. In PSTN, the access segment is based on twisted pair. Expenses for network infrastructure will grow, as the copper cable is still being used in access network and prices for copper are growing, along with costs of design, construction and maintenance of these networks. Because of this, a constant active search for new decisions has been taking place, especially in recent years. The aim of this search is the creation of more perfect equipment for existing twisted pairs, the development of access networks based on coaxial and fiber optic cables, wide application of Wireless Local Loop (WLL), *etc.* Another key factor affecting the evolution of access networks is determined by the necessity of providing new services in voice, data and video information on interactive and broadcasting mode.

Requirements for a wider bandwidth in access networks are determined by new multimedia applications resulting from the internet and video systems. Accelerated growth of WWW pages with powerful video information and a number of similar applications require high bit rates of up to tens of Mbit/s. Services like Digital Video Broadcasting (DVB), Video-on-Demand (VoD) and interactive TV create high-speed multimedia traffic which cannot be transmitted without broadband access network support. Broadband access provisioning is nowadays a key factor for the majority of modern applications. The solution to the broadband access problem will satisfy the needs of subscribers and allow them to get maximum profit from the development of new services.

Various access technologies can be selected depending on the infrastructure of access networks (twisted pair, coaxial cable, fiber optic cable, hybrid structure 'fiber/coax', wireless access). Among the large different access techniques, the family of technologies under the common name xDSL should be mentioned first. High-speed xDSL technologies providing access bit rates of several Mbit/sec via twisted pairs appeared on the telecommunications market in the middle of the 1990s. The application of xDSL technologies is effected mainly by public operators controlling large-scale local telephone networks based on standard telephone copper cables. The second important trend in access networks is related to the application of cable modems in Cable TV networks to provide interactive broadband services with bit rates of up to several tens Mbit/s. In recent years, hybrid cable systems with both coaxial and fiber optic (Hybrid Fiber/Coax, HFC) cables have been used in Cable TV networks on access segment. Such networks are designed to provide a wide range of services, TV, high-speed access to the internet and telephony included. In some countries, only fiber optic cables (Fiber-to-the-Home (FTTH) technology) were used in an access segment. However, this solution, which is based on laying fiber to home, is very expensive and is not likely to find wide application in the nearest future. In cases where the construction of cable access networks becomes economically ineffective, wireless access systems find more and more application. Systems based on cellular mobile technologies, such as GSM, GPRS, EDGE and UMTS, and also Wireless LAN (WLAN) and Wireless Local Loop (WLL) technologies, should be mentioned.

Modern WLANs are based on the IEEE 802.11 set of standards issued by the American Institute of Electrical and Electronics Engineers (IEEE). This set of IEEE standards is known under the common name Wi-Fi (short for 'wireless fidelity'). Wi-Fi networks operate in two unlicensed frequency bands – the Industrial, Scientific and Medical (ISM) band at 2.4 GHz, and the Unlicensed National Information Infrastructure (U-NII) band at 5 GHz. This means that these frequencies may be used by anybody without licence or interference from radio transmission used by the military, air traffic control, *etc.* There are three variants of 802.11 wireless networks with actual data rates from several Mbit/s to several tens of Mbit/s, and with coverage areas of up to 100 metres. Wi-Fi has gained acceptance in many businesses, agencies, schools and homes as an alternative to a wired LAN. Many airports, hotels and fastfood facilities offer public access to Wi-Fi networks. These locations are known as hotspots. An interconnected area of hotspots and network access points is known as a hot zone.

Another type of promising wireless access technology is WiMax (short for Worldwide Interoperability for Microwave Access). WiMax technology is defined in the IEEE 802.16 set of standards and is designed for Wireless Metropolitan Area Networks (Wireless MANs). It offers broadband access at 70 Mbps over distances of 50 kilometres (30 miles). The target of WiMax technology is to deliver multimedia wireless access services in metro areas, enabling networks to have an effective wireless last mile solution.

3.8 *The digital divide challenges*

In recent years, as the IC2T sector has become the backbone of the global information economy, increasing attention has focused on the gap in the access to information resources in some countries compared with those with state-of-the-art networks: telephone, radio, TV, internet, satellite; in short, anything that can be considered IC2T.

This gap has come to be known as the 'digital divide'. The concept of the digital divide expresses the difference in facilities for people to communicate, relative to their geographic location, their living standard and their level of education. In developed countries, cellular communications, cable TV and the internet have become regular services to hundreds of millions of private users, while in less developed countries a single telephone line could be shared by hundreds of inhabitants. In developing countries, the majority of the population rarely or never uses any IC2T owing to the different reasons mentioned above.

Despite the boom in the access to communication resources during the past fifteen years (from 700 million to nearly 2.7 billion telephone lines, including fixed and mobile phones, and from less than one million to more than a hundred million internet users), the differences in the usage of communication resources between developed countries and developing countries, and also between different groups of people within the countries, are maintained. The differences between developed and developing economies can be seen in the level of penetration of different IC2T services (telephone, mobile phone, internet) and of personal computers. In Tables 1–4, (Desurvire, 2004b) a number of indicators describing a level of penetration of different IC2T services for the world as a whole, and also for three groups of countries – with high income, with low income and a group of least developed countries are presented.

Table 1 World data profile

<i>Indicators</i>	<i>1999</i>	<i>2002</i>	<i>2003</i>
Fixed lines and mobile telephones (per 1000 people)	234.2	363.8	405.7
Personal computers (per 1000 people)	69.1	100.8	...
Internet users (per 1000 people)	58.7	130.9	149.9
Population, total, billion	6.0	6.2	6.3
GNI per capita, Atlas method (current US\$)	5,060.0	5,130.0	5,510.0

Table 2 Data profile for group of countries with high income

<i>Indicators</i>	<i>1999</i>	<i>2002</i>	<i>2003</i>
Fixed lines and mobile telephones (per 1000 people)	960.3	1249.7	1267.5
Personal computers (per 1000 people)	341.6	466.5	...
Internet users (per 1000 people)	186.8	364.2	376.8
Population, total, billion	0.948	0.967	0.972
GNI per capita, Atlas method (current US\$)	25,910.0	26,570.0	28,600.0

Table 3 Data profile for group of countries with low income

<i>Indicators</i>	<i>1999</i>	<i>2002</i>	<i>2003</i>
Fixed lines and mobile telephones (per 1000 people)	20.4	39.4	55.7
Personal computers (per 1000 people)	3.6	6.9	...
Internet users (per 1000 people)	1.5	8.1	16.2
Population, total, billion	2.1	2.3	2.3
GNI per capita, Atlas method (current US\$)	380.0	400.0	440.0

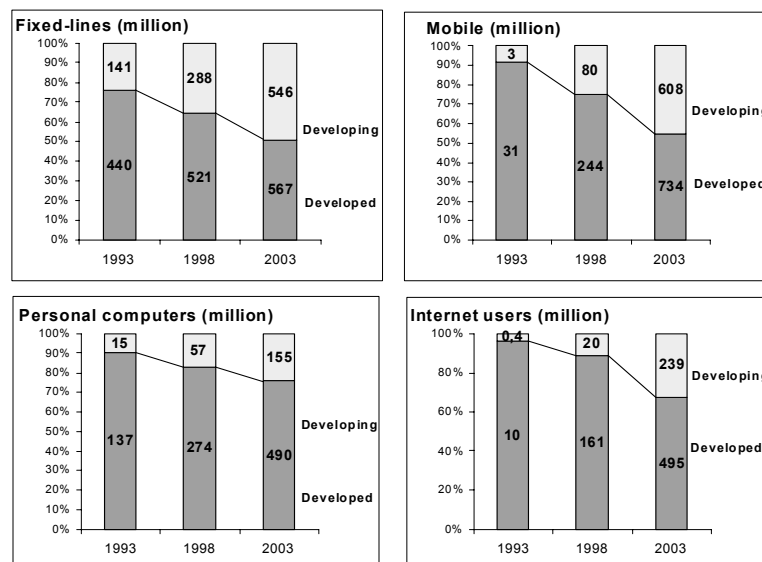
Table 4 Data profile for group of least developed countries

Indicators	1999	2002	2003
Fixed lines and mobile telephones (per 1000 people)	6.3	17.7	24.2
Personal computers (per 1000 people)	2.1	4.2	...
Internet users (per 1000 people)	2.0	4.0	13.5
Population, total, billion	0.619	0.660	0.675
GNI per capita, Atlas method (current US\$)	280.0	290.0	310.0

Nevertheless, the growth in mobile penetration, the boom in the internet, the fast development of wireless access, based, especially, on such technologies as WiFi and WiMax, are considered main factors which should help to reduce the digital divide. Widening access to basic infrastructure will play an important role on the IC2T sector’s growth in developing countries. Submarine fiber-optic cables have been extensively deployed over the last decade, connecting the most remote locations to the internet, which is complemented at local or continental level by satellite communications. A shift from fixed to wireless network infrastructure may also compensate for failed development, degradation or obsolescence of old telephone systems. With appropriate help, LDCs will be able to catch up rapidly with the internet, and not just in business, but also in schools, universities, hospitals and clinics.

The gap between developed and developing economies has narrowed markedly, with particularly rapid progress in the case of mobile phones and internet users (see Figure 3).⁶ With respect to mobile phones, the number of users in the developing world has grown from just 3 million in 1993 to some 608 million a decade later. In the case of the internet, the respective numbers are 0.4 and 239 million.

Figure 3 Internet reduction of digital divide – percentage share between developed and developing countries of fixed lines, mobile phones, personal computers and internet users in 1993, 1998 and 2003



Source: ITU World Telecommunication Indicators Database

Nevertheless, given that the developing world accounts for more than 80% of the global population, there is still a long way to go to essentially reduce the digital divide. Even if national populations were growing at similar rates, and current IC2T growth rates will be sustained, it would take 10–15 years for this gap to be bridged. Furthermore, given that more than a billion of the world's developing country population lives on less than USD2 per day, it is likely that the fundamental nature of the digital divide will be kept, in expectation of essential socioeconomic changes.

3.9 Information/knowledge management in the networkcentric world

Given the universality of WHIG, a user accessing this network must be able to obtain critical information and knowledge required at a given point in time, as well as easily upload necessary and relevant data. As noted at the start of the paper, the politics and economies of the world have divided it into two entities – Barnett's functioning core and the nonintegrating gap (Gronlund, 2002). However, if WHIG is to be successful and provide a partial means to alleviate this divide rather than exacerbate it further, it is vital that, irrespective of location, the same confidence in access to and quality of information is maintained. The quality and access to information, capability to upload or transfer it must be equally well supported and available to any potential user anywhere on the globe, and neither the manner of interaction with the WHIG nor the employed technologies will be able to deter the transmitted message or information from being understandable, useful and useable (Daft and Lengel, 1986; Daft *et al.*, 1987; Galbraith, 1977).⁷

4 Knowledge creation and management in networkcentric healthcare

The preceding section describing IC2T developments has detailed the essential components that constitute the grid system of WHIG and serve to interconnect its formation acquisition entities (sensors) with its information processing and disseminating components (nodes) (ref Figure 1). The WHIG network comprises an interwoven variety of telecommunicating devices allowing direct and uncomplicated transfer of information and data. In order to ensure such a seamless transformation to take place, it also becomes necessary to incorporate the sophisticated information and knowledge management techniques needed to ensure that the informational content is relevant and useful. Information management within WHIG focuses on the correctness and completeness of used data and information, and eliminates redundancies. Knowledge management, on the other hand, employs a wide range of tools and techniques to facilitate continuous capture, storage, use and reuse and dissemination of pertinent information to aid critical decision making (Larson, 2004; Lengel and Daft, 1988; Wickramasinghe and Schaffer, 2005).

In the networkcentric environment of WHIG, the three essential elements of the grid architecture are the smart portal, which provides the entry point to the network, the analytic nodes and the intelligent sensors (Figure 1) (Kyprianou, 2005; von Lubitz and Wickramasinghe, 2005a; 2006; Wickramasinghe, 2005b). Moreover, these three elements also make up the principal technologies supporting and executing critical data, information and knowledge exchanges that are the basis of knowledge management in the networkcentric world papers (Kyprianou, 2005; von Lubitz and Wickramasinghe, 2005b; 2006; Wickramasinghe, 2005b; von Lubitz and Wickramasinghe, 2005a). Viewed

as a functional element of networkcentricity and cardinal to ensuring effective KM is the design and development of adequate infrastructure and architecture (von Lubitz and Wickramasinghe, 2006; Alavi and Leidner, 1999; Pfeffer and Sutton, 1999; Probst *et al.*, 2000; Wickramasinghe, 2005a) that support the transfer of and/or access to information and data throughout the system. Moreover, it is essential that this occur with a high level of confidence (von Lubitz and Wickramasinghe, 2006; Probst *et al.*, 2000; Wickramasinghe, 2005a). It is of particular significance in HNCO that the design and development efforts occur in parallel with the design and development of the physical network and grid structures, *i.e.*, telecommunications platforms, since it is the grid structure rather than the key operational WHIG components (smart portal, analytic nodes and sensors) that play a key role in facilitating the transfer of information and data among the users. Such an approach necessitates application of the ideas borrowed from knowledge governance and concepts of I*I (information integrity) (Wickramasinghe and Lichtenstien, 2005; Mandke *et al.*, 2003; Wickramasinghe and Fadlalla, 2004) that will ensure the unimpeded consistency of message transfer, its quality and content independent of format or form. Thus, if a dial-up modem provides the sole access to WHIG, the information needs to be presented in a text form rather than high-resolution, elaborate glossy figures whose download time may be incompatible with the time limits at the disposal of the end user (*e.g.*, a nurse dealing with a severely traumatised patient in a remote rural village).

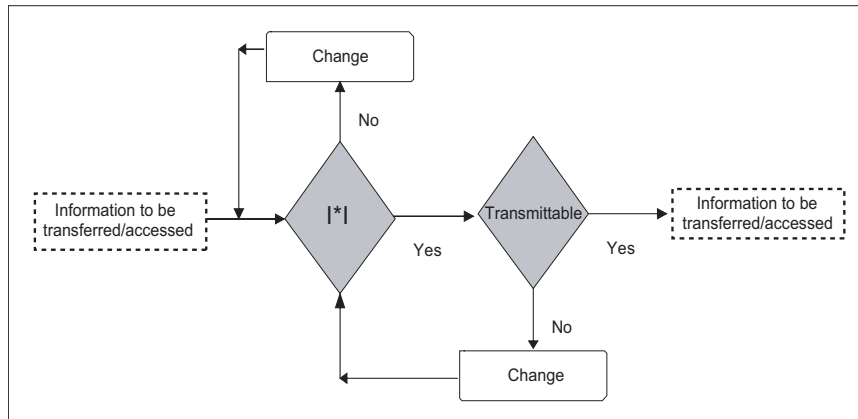
The process of knowledge governance focuses on structuring processes pertinent to information dissemination, transfer, and/or retrieval and ensuring that both information and data content are always consistent, not only with the organisational KM objectives but also with the goals and strategies of the organisation as such Huang *et al.* (1999), Weill and Woodham (2002) and Wenger (1996). For such consistency to arise, a framework that ensures delivery of anticipated or predicted benefits of a service or process in an authorised and regulated manner must be adopted. Such a framework also forms the context for the continual analysis and management of risk. Moreover, it facilitates the continuous development of strategies to manage organisational knowledge over time as updates and other changes occur. The idea of governance has its roots in two areas (Bush, 2004; Webster, 2002; van den Berghe and De Ridder, 1999): the shareholder model in which the organising framework of governance is centred around serving the shareholder's interest and value, and the stakeholder model where the governance embraces the needs of a broad spectrum of interests, including owners, employers, creditors and even the local community. For networkcentric operations, knowledge governance requires developing an organising framework to ensure that all WHIG users are able to access and/or disseminate germane knowledge and pertinent information irrespective of their location or IC2T infrastructure constraints. Moreover, such data, information and knowledge must constitute an accurate representation of issues pertaining to healthcare and all peripheral but relevant issues; *i.e.*, they must satisfy the information integrity criteria defined for WHIG (Figure 4 and Table 5). It is important to note that while the framework itself will remain relatively unchanged, the criteria used to judge both consistency of information content and I*I should be continuously evaluated and updated as required.

Table 5 Information integrity

<i>Component</i>	<i>Key dimensions</i>
Accuracy	Information must be correct: Information content accuracy Process logic correctness and accuracy System accuracy to specifications
Reliability	Information must be from a sound source and verifiable: Information currency Information auditability
Consistency	Information must not change unless the circumstances themselves change: Content consistency Temporal/spatial consistency Relational consistency Process/system consistency Standardisation
Completeness	Information should contain all available data element: Collectively exhaustive Minimal missing data points
Usefulness	Information that is stored and accessed must be required for a specific tasks: Information relevancy Germane knowledge Value added characteristic
Usability	Information that is stored and accessed must be in a form that it can be applied to a given context easily: Information simplicity Information portability
Manipulability	Information should be able to support understanding, decision making and analysis: Content richness Contextual coverage

Source: Wickramasinghe and Lichtenstien (2005); Mandke *et al.* (2003) and Wickramasinghe and Fadlalla (2004)

Figure 4 Framework of major knowledge governance decisions in HNCO. Information that is to be transferred and/or accessed must satisfy both the tenants of I*I as well as be in an appropriate format to transmit, if this doesn't occur changes to the information are required keeping in mind however that the content of the message remains unchanged



5 Conclusion

It sounds trivial since the message has been repeated over and over again in both the popular press and in the most learned scientific journals: healthcare is in crisis, nationally and globally. For once, European, US, and WHO authorities and politicians concur. Yet, while HER is advocated as the technological means of changing the grim picture, we believe this is, at best, only a partial solution that will not address many of the fundamental problems currently faced by healthcare. While the business of healthcare is, indeed, about providing an individual with easy access to the healthcare professional, and providing the healthcare professional with tools to provide adequate healthcare, the entire process takes place in a vastly more complicated environment of economies, policies and politics, and, far too frequently – conflicts. We believe, therefore, that similar to the two other fields of human activity to which healthcare is (maybe unfortunately) also related – business and war – healthcare needs to expand its incursion into the world of IC2T to the concept of networkcentricity and pursue it with utmost vigour. As already demonstrated in military operations (Sveibly, 1997), networkcentric operations increase efficiency, reduce cost, and increase chances of success. Global healthcare is an equally complex environment where the benefits of networkcentric operations can bring similar advantages to those realised by the military application of the networkcentricity concept.

Networkcentricity clearly offers a solution to healthcare's growing problems and the current advances in IC2T provide us with the appropriate building blocks of WHIG. We have argued in the present paper that the telecommunications architecture and infrastructure are the cornerstones of WHIG that assure adequate, consistent and unimpeded 'blood flow' of information and knowledge that, in turn, is the essential prerequisite to the networkcentric concept. We have also argued that, despite claims to the contrary, the technological gap that separates the rich Western world from the often desperately poor underdeveloped or developing ones is beginning to narrow. We also believe that efficient telecommunications will be the essential tool to narrow the 'gap' of

Barnett (Gronlund, 2002), since it is by these means that large-scale commerce and freedom of expression can be disseminated most readily. Theoretically then, the world is rapidly becoming ready for the implementation of networkcentric healthcare. The necessary technologies are already in routine use, and the billions of dollars spent on often futile projects can provide more than adequate support for the needed technological and intellectual expansion in the still deficient parts of the globe. Moreover, incorporation of tools and techniques provided by such disciplines as knowledge management will ensure that accurate and pertinent information is accessed at all times and anywhere. In the preceding pages, we have outlined a vision for healthcare that is not that of a distant future. Yet, it is now that this vision must be made a reality, since healthcare problems have ceased to be those of our distant neighbours, living in distant parts of the world and mentioned only when wars or cataclysms occur. As many illnesses, sometimes to our surprise (*e.g.*, hypertension in the Third World), became global, healthcare too became a global issue. Yet, what is lacking in addressing this very rapidly growing concern is the foresight of a critical mass of key people to implement a global solution based on technologies that made globality possible in the first place: IC2T. Networkcentricity represents a major transformation where the combination and unification of evolutionary steps already made results in revolutionary outcomes, and we believe that without the implementation of HNCO, healthcare will continue to struggle in its current state and the disparity between the functioning core and the nonintegrating gap will continue to grow.

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Notes

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