# Chapter XVII
# Third Generation (3G) Cellular Networks in Telemedicine:
## Technological Overview, Applications, and Limitations

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## ABSTRACT

*The evolutions in the field of telecommunications technologies, with the robustness and the fidelity these new systems provide, have significantly contributed in the advancement and development in the field of medicine, and they have also brought forth the need for their utilisation in the healthcare sector Thus, telemedicine and e-Health have clearly started to become an important issue for implementation, operational deployment of services and a promising market for industry. Recognizing this trend, its importance in the lives of citizens all around the globe and its contribution in the daily healthcare delivery by all actors involved in the procedure, the authors of this chapter attempt to familiarize the readers with the impact that high broadband wireless networks have upon telemedicine services and with the way they facilitate the secure transmission of vital information stemming from bandwidth demanding applications in real time. After providing the readers with an overview of telemedical services and commenting on how they can offer added value to existing healthcare services, they provide an analysis of the wireless infrastructure that has facilitated telemedical services over the years, and point out the significant role that the third generation telecommunications systems can play in the field. After that, follows an analysis* *of the range of new applications that can be supported by the 3G telecommunications infrastructure, and the related research that has taken place in the European level regarding the utilization of 3G networks for telemedical applications. However, 3G networks are not a panacea; for this reason the limitations of this infrastructure is also stressed out. The authors conclude by discussing whether 3G networks can prove to be an attractive solution for telemedical services to healthcare providers.*

## INTRODUCTION

The evolutions in the field of telecommunications technologies, with the robustness and the fidelity these new systems provide, have significantly contributed in the advancement and development in the field of medicine; they have also brought forth the need for their utilisation in the healthcare sector, a sector that is information intensive and knowledge demanding. Thus, e-Health solutions are of crucial importance (Olsson & Lymberis & Whitehouse, 2004, p.312); telemedicine and e-Health have clearly started to become an important issue for implementation, operational deployment of services and a promising market for industry (Wooton, 1999) ("EU2004a", 2004). As had been forecasted a decade ago, healthcare institutions make extensive use of computer networks, mass storage devices, and sophisticated workstations at which humans and machines interact, assisted by advanced information processing tools and techniques of knowledge engineering, to achieve integration of multimodality multimedia, diagnostic data and expert medical knowledge (Orphanoudakis & Kaldoudi & Tsiknakis, 1996, 210). However, telemedicine is not a brand new service. On the contrary, telemedicine has been described from as early as as 1906, when W.Einthoven described the possibility of transmitting cardiogram information via telephone lines. This description became a reality in 1910 when S.G. Brown did actually transmit hearing sounds in London. In addition, a few years later, and more specifically in 1920, wireless communications were utilized in order to provide medical advice support in boats from the Norwegian hospital Haukeland.

Since 2004, the term eHealth aroused, defined by Eysenbach as: "eHealth is an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. In a broader sense, the term characterises not only a technical development, but also a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve healthcare locally, regionally and worldwide by using information and communication technology"(Eysenbach, 2001, e20), (Pagliari et al, 2005, e9). The term eHealth is supposed to be an overall term, or even better an "umbrella" term, including all aspects of Health Telematics.

Telemedicine is one of the areas canopied under the umbrella-term – eHealth. The term 'telemedicine' derives from the Greek 'tele' meaning *'at a distance'* and the present word 'medicine' which itself derives from the Latin 'mederi' meaning *'healing'*. However, even though this service has been attributed many terms, there is not actually a standardized definition of it. On the contrary, various organizations have come up with different definitions of the term telemedicine. Thus for example, the World Health Organisation defines telemedicine as the delivery of healthcare services, where distance is a critical factor, by healthcare professionals using information and communications technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of healthcare providers, all in the interest of advancing the health of individuals and their communities (W.H.O., 1998). The Norwegian Center of Telemedicine on the other hand defines telemedicine as the research, the follow-up and the management of patients, as well as the education of patients and personnel, making use of systems that allows the direct access in patient data and the advisory services of experts, anywhere they might be located (Norwegian Centre for Telemedicine 2007). Furthermore, the Journal of Telemedicine & Telecare defines telemedicine as the medicine practiced from a distance, and as such, encompasses not only the diagnosis but the treatment, as well and in addition the medical education (Journal of Telemedicine and Telecare 2007). Even though not clearly defined however, telemedicine targets towards the qualitative healthcare provision for all citizens, trying to diminish and if possible eliminate geographical and/or economical barriers.

## TELEMEDICINE SERVICES

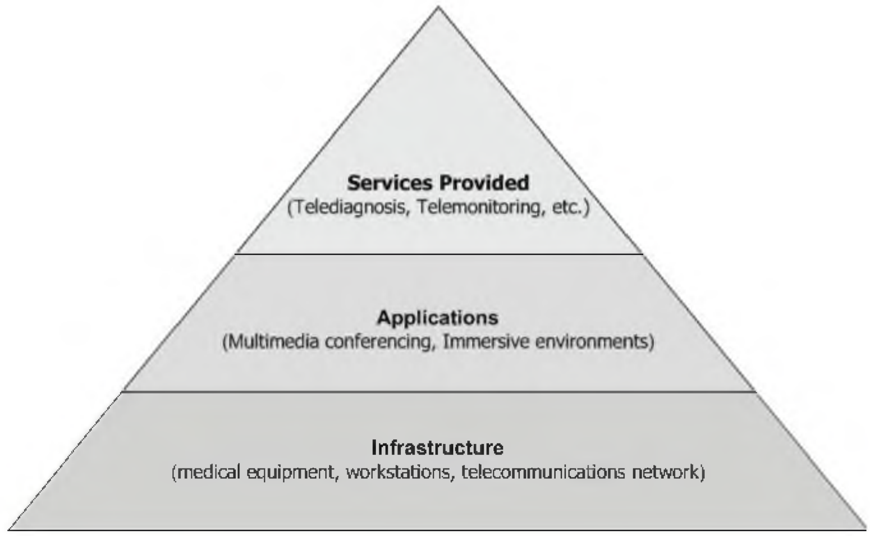
Telemedicine services are currently employed to support various aspects of healthcare delivery, such as remote consultation (physician-physician or patient-physician) for diagnostic purposes, remote guidance and performance of a variety of therapeutic and surgical procedures thus making expertise available at remote sites (e.g. site-of-an accident, geographically isolated places, on board ships and planes, sea-plants, battle-fields, hazardous environments, space stations, etc), real-time access to educational material and statistical information on a global basis and remote use of distributed complementary facilities for medical information processing. Furthermore, an important goal of telemedicine is to guarantee continuity of care, rendering the medical history of a patient readily, timely and transparently available wherever and whenever needed.

Telemedicine/telehealth consists of a set of added-value telematic services, implemented over an advanced telecommunications infrastructure and supported by different information technologies and related applications. Its main goal is to provide different levels of support for remote monitoring, preventive, diagnostic and therapeutic medical procedures. Therefore, telemedicine can be considered as an extended virtual healthcare institution that encompasses available physical and human resources over a wide region in order to support remote medical procedures and patient management.

The emerging environment in which healthcare telematics services can be provided has a layered structure (Orphanoudakis & Kaldoudi & Tsiknakis, 1996, 210). The top layer corresponds to the actual services provided, such as tele-diagnosis, tele-monitoring, tele-consultation, tele-management, and other added-value services. The second layer consists of all computer applications that provide the necessary communications and computer supported cooperative working environment for telemedicine services to be realized. Such applications include electronic mail, multimedia conferencing, synchronous and asynchronous consultation, immersive environments and tele-presence, interactive image analysis and visualization of multimedia medical data, tools for querying geographically distributed medical databases, and a variety of other applications that facilitate added-value information services. The bottom layer corresponds to the hardware and software infrastructure that supports the aforementioned applications and consists primarily of medical equipment, distributed workstations, the telecommunications network, and tools for the management of network and other resources.

The primary goal of telemedicine is to provide support for remote expert consultation based on locally acquired medical data and remote guid-

*Figure 1. Layered structure of healthcare services environment*




ance for locally performed medical procedures. Thus, telemedicine can cover a wide variety of medical needs, including provision of healthcare in remote areas, in transportation means, emergency telemedicine, homecare, tele-education, homogenisation of medical services and others. Different services are described as follows, based on the specific objectives of each telemedicine session.

## Tele-Diagnosis

Typically, this service involves asynchronous point-to-point communication and requires relatively simple applications and a minimum infrastructure. In response to a request by a remote site, which transmits all or selected data of a diagnostic examination, specialists at a referral medical center review these data and return a diagnostic report to the requesting site. Tele-diagnosis is particularly useful for rural and other areas that are not well served by specialized medical personnel.

## Tele-Monitoring

Video sequences of the examination room and the patient are transmitted to the expert, who monitors the procedure and interacts with the examination site through an image and voice data link. This service may also include transmission of vital biosignals and other related data, as in the case of home care telemedicine services. However, the requirement for real-time multimedia communication imposes additional technological demands on the available infrastructure.

## Tele-Consultation

Providing a shared workspace among remotely located medical experts is one of the main functions of the tele-consultation service. This service requires the synchronous viewing and manipulation of the same set of medical multimedia data, as well as the real-time exchange of comments among all parties involved in the session. It is evident that the synchronization of the media and procedures involved in a tele-consultation session requires various types of complex transactions and resource management mechanisms, thus imposing serious demands on the underlying applications. Furthermore, the real-time nature of the service and the volume of multimedia data exchanged require a technologically advanced infrastructure.

### Tele-Management

The combination of advanced tele-monitoring and tele-consultation services, with remote resource sharing, offers the possibility for the telematic management of diagnostic and therapeutic procedures. This service is gaining momentum together with parallel developments in the areas of broadband conventional and mobile communications, virtual reality and tele-presence (Kalawsky, 1993). Advances in computer assisted medical interventions, automatic surgical tools, and various forms of remote sensing, have already paved the way towards advanced telemedicine services in endoscopy and surgery.

### Tele-Education

Distant learning in telemedicine can also be accomplished by special interactive tele-education sessions and the distribution of specially prepared educational material, such as hypermedia diagnostic imaging textbooks. Medical training has a lot to benefit from the development of wide area, medical education environments over high-speed networks.

### Added-Value Services

Telemedicine is not limited to communication and collaboration among experts. Of increasing importance are added-value telemedicine services, which enable the sharing of a variety of other resources necessary for extending and improving the quality of healthcare procedures. For example, telemedicine can provide access to high-performance computing centers for advanced medical image processing and 3D visualization. Other added-value telemedicine services involve the retrieval of reference material from remote databases, such as on-line medical publications and digital atlases of the human anatomy. The sharing of such information is a valuable medical decision support tool and promotes the continuing education of medical personnel.

Thus, it is more than obvious that telemedicine can offer a plethora of advantages. If we were to summarize these advantages, we could say that telemedicine could offer:

- Equal rights of access in the services of health for the all citizens.
- High quality services of health to citizens of remote regions.
- Solution for management and organization problems to remote, underserved and with few resources primary point-of-care units
- Modernization of work environment
- Cross-check diagnosis
- Diffusion of medical information
- Smart management of medical resources
- Cost reduction
- Reduction of pointless travel

## TECHNOLOGICAL INFRASTRUCTURE

It is therefore obvious that as the request for telemedical services is constantly rising and becoming even more demanding, the bottom layer of the structure, namely the infrastructure layer should become equally capable of providing such services. One such demand is the available bandwidth of the telecommunications networks. In the following paragraphs, the significant role that the third generation telecommunications systems - that are only recently being deployed in Europe - can play, as regards telemedical applications, is pointed out. The transition from 2G and 2.5G to 3G telecommunications systems could prove to be crucial, especially in relation to emergency telemedicine.

## GSM

It is beyond doubt as well that the great outburst in mobile communications occurred in the mid 1980s, with the appearance of GSM (GSMWorld: GSM, 2007). During the early 1980s, analog cellular telephone systems were experiencing rapid growth in Europe, particularly in Scandinavia and the United Kingdom, but also in France and Germany. Each country developed its own system, which was incompatible with everyone else's in equipment and operation. This was an undesirable situation, because not only was the mobile equipment limited to operation within national boundaries but there was also a very limited market for each type of equipment. Thus, in 1982 the Conference of European Posts and Telegraphs (CEPT) formed a study group called the Groupe Spécial Mobile (GSM) to study and develop a pan-European public land mobile system. In 1989, GSM responsibility was transferred to the European Telecommunication Standards Institute (ETSI), and phase I of the GSM specifications were published in 1990. Commercial service was started in mid-1991, and by October 1997 GSM subscribers had grown to more than 55 million. GSM is not only a European standard. Over 200 GSM networks (including DCS1800 and PCS1900) are operational in 110 countries around the world.

As allocated by the ITU, GSM 900 utilizes the 890 – 915 MHz for the uplink and the 935 – 960 MHz for the downlink, GSM 1800 utilises the 1710 – 1785 MHz for the uplink and the 1805 – 1880 MHz for the downlink and GSM 1900 utilises the 1850 – 1910 MHz for the uplink and the 1930 – 1990 MHz for the downlink. GSM services are not limited to telephony but include asynchronous and synchronous data services (2.4/4.8/9.6 Kbps), value-added features (SMS, fax) and more (Dechaux & Scheller, 1993). As with all other communications, speech is digitally encoded and transmitted through the GSM network as a digital stream. GSM users can send and receive data, at rates up to 9600 bps, to users on POTS, ISDN, Packet Switched Public Data Networks, and Circuit Switched Public Data Networks using a variety of access methods and protocols (Dubendorf, 2003).

The network behind the GSM system seen by the customer is large and complicated in order to provide all of the services which are required:

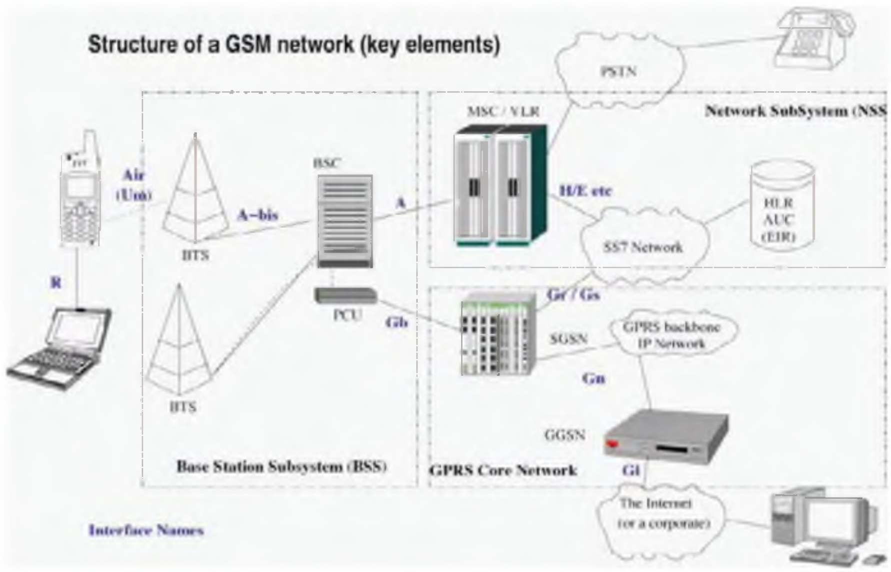
- The Base Station Subsystem (the base stations and their controllers).
- The Network and Switching Subsystem (the part of the network most similar to a fixed network). This is sometimes also just called the core network.
- The GPRS Core Network (the optional part which allows packet based Internet connections).

All of the elements in the system combine to produce many GSM services such as voice calls and SMS.

The method chosen by GSM to divide up the bandwidth among as many users as possible is a combination of Time- and Frequency-Division Multiple Access (TDMA/FDMA). The FDMA part involves the division by frequency of the (maximum) 25 MHz bandwidth into 124 carrier frequencies spaced 200 kHz apart. One or more carrier frequencies are assigned to each base station. Each of these carrier frequencies is then divided in time, using a TDMA scheme. The fundamental unit of time in this TDMA scheme is called a burst period and lasts 15/26 ms (or approx. 0.577 ms). Eight burst periods are grouped into a TDMA frame (120/26 ms, or approx. 4.615 ms) (Dubendorf, 2003).

From the point of view of the consumers, the key advantage of GSM systems has been higher

*Figure 2. The structure of a GSM network (WikiPedia: GSM 2007)*




digital voice quality and low cost alternatives to making calls such as the Short Message Service (SMS). The advantage for network operators has been the ability to deploy equipment from different vendors because the open standard allows easy inter-operability. Like other cellular standards GSM allows network operators to offer roaming services which mean subscribers can use their phones all over the world.

## GPRS

GPRS (short for general packet radio service) was recently introduced as the packet-mode extension

*Table 1. GPRS Multislot Classes*

| Multislot Class | Downlink Slots | Uplink Slots | Active Slots |
|---|---|---|---|
| 1 | 1 | 1 | 2 |
| 2 | 2 | 1 | 3 |
| 3 | 2 | 2 | 3 |
| 4 | 3 | 1 | 4 |
| 5 | 2 | 2 | 4 |
| 6 | 3 | 2 | 4 |
| 7 | 3 | 3 | 4 |
| 8 | 4 | 1 | 5 |
| 9 | 3 | 2 | 5 |
| 10 | 4 | 2 | 5 |
| 11 | 4 | 3 | 5 |
| 12 | 4 | 4 | 5 |
| 32 | 5 | 3 | 6 |

*Table 2. GPRS upload & download rate per technology*

| Technology | Download (kbps) | Upload (kbps) |
|---|---|---|
| CSD | 9.6 | 9.6 |
| HSCSD | 28.8 | 14.4 |
| HSCSD | 43.2 | 14.4 |
| GPRS | 80.0 | 20.0 (Class 8&10 and CS-4) |
| GPRS | 60 | 40.0 (Class 10 and CS-4) |
| EGPRS (EDGE) | 177.6 | 118.4 (Class 10 and MCS-9) |

to GSM and constitutes the lead-in to 3G telecommunications technologies. The first GPRS trials were conducted in the year 1999, while the first GPRS networks rolled out in the year 2000, the same year the first GPRS terminals were released (GSMWorld: GPRS, 2007).

GPRS is a new non-voice, value added, high-speed, packet-switching technology for GSM networks. It facilitates sending and receiving small bursts of data, such as email and web browsing, as well as large volumes of data over a mobile telephone network. Its main innovations are that it is packet based, it increases data transmission speeds, and extends the Internet connection all the way to the mobile PC – the user no longer needs to dial up to a separate ISP (Dubendorf, 2003). GPRS users are considered to be always connected. Packet switching means that GPRS radio resources are used only when users are actually sending or receiving data.

GPRS speed is a direct function of the number of TDMA time slots assigned, which is the lesser of (a) what the particular cell supports and (b) the maximum capability of the mobile device expressed as a GPRS Multislot Class. Transfer speed depends also on the channel encoding used. The least robust (but fastest) coding scheme (CS-4) is available near the Base Transceiver Station (BTS) while the most robust coding scheme (CS-1) is used when the Mobile Station (MS) is further away from the BTS (WikiPedia: GPRS, 2007).

Using the CS-4 it is possible to achieve a user speed of 20.0 kbit/s per time slot. However, using this scheme the cell coverage is 25% of normal. CS-1 can achieve a user speed of only 8.0 kbit/s per time slot, but has 98% of normal coverage. Newer network equipment can adapt the transfer speed automatically depending on the mobile location. Theoretically, a GPRS connection can provide a data transmission speed of up to 171.2 Kbps (approximately three times as fast as the data transmission speeds of fixed telecommunications networks and ten times as fast as the current GSM network services) if eight slots are used. However, it is unlikely that network operators will allow a single user use up all the time slots. Therefore, maximum GPRS speeds should be compared against constraints in the GPRS terminals and networks. Nevertheless, bit rates up to 56 Kbps are achievable. The fewer the timeslots provided per user, the lower the data transmission speed.

## UMTS

UMTS stands for Universal Mobile Telecommunication System and constitutes Europe's implementation of the 3G Telecommunications Systems. These new systems are a significant innovation over 2G and 2.5G systems because of their high operating flexibility, their ability to provide a wide range of applications and generally extend the services now provided to fixed networks users to mobile customers. 2G systems provide limited capabilities for real-time transmission of data and are limited in terms of maximum data rate. 3G mobile and wireless networks provide 144 kbps for full mobility applications, 384 kbps for limited mobility applications in macro and micro cellular environments and 2 Mbps for low mobility applications, particularly in the micro and pico-cellular environments (Muratore, 2001).

Contrary to the current GSM systems, UMTS allows for broadband data communication to mobile units, packet-based transmission of text, digitized voice, video, and multimedia, offering a set of services to mobile computer and phone users no matter where they are located in the world. The World Administrative Radio Conference that is responsible for assigning radio frequencies on a worldwide basis assigned a band between 1885 and 2025 MHz as well as between 2110 and 2200 MHz to 3G systems (Mandyam & Lai, 2002). In Europe, the first 15 MHz of the band coincided with part of the band currently used by the DECT system. The remaining portion of the spectrum for the terrestrial segment has been divided into a "paired" part (from 1920 to 1980 MHz for the uplink and from 2110 to 2170 MHz for the downlink) and an "unpaired" part (35 MHz, from 1900 to 1920 MHz and from 2010 to 2025 MHz) where there is no a-priori distinction between the portions assigned to the up-link and down-link, respectively (Holma & Toskala, 2000).

In order to maximize the number of users served per cell UMTS utilizes the CDMA technique (Code Division Multiple Access) which belongs to the family of spread spectrum techniques (Castro, 2001). Systems with CDMA access techniques enable users to transmit at the same frequency simultaneously, thus giving the ability to superimpose several signals on the same radio channel. In CDMA networks, all terminals use the same radio frequency. In networks with TDMA or FDMA access such as GSM, the terminal engaged in a call continuously measures the level and the quality of the signal received from the cells adjacent to the cell where it is currently located, as well as the radio channel carrying the call in progress (Muratore, 2001). This measurement is sent to the network on a channel associated with the one which is active between the network and the terminal. CDMA systems can provide fully asynchronous hand-over functions as well as the means for active connection maintenance between the mobile terminal and the network, over several radio links, which can also be activated through different radio base stations. In the channel changing stage, typical of the hand-over process, connection continuity is guaranteed through the multiple paths set up between the mobile terminal and the "controlling point" in the network, whereas in GSM for example, channel changing takes place by means of a "hop" between the radio channels of the two cells involved in the process, and hence through an "interruption" whose duration must necessarily be limited. In other words, in order to improve communication quality, the mobile terminal does not limit itself on remaining connected to a single Base Station but involves all Base Stations from which it receives a sufficiently good reference signal in the communication. The process of activating and releasing parallel links is carried out as a function of the quality of the signal received by the mobile terminal as it moves in the network.

Since 2006, UMTS networks in many countries have been or are in the process of being upgraded with High Speed Downlink Packet Access (HSDPA), sometimes known as 3.5G. Currently, HSDPA enables downlink transfer speeds of up to 3.6 Mbit/s. Work is also progressing on improving the uplink transfer speed with the High-Speed Uplink Packet Access (HSUPA). Longer term, the 3GPP Long Term Evolution project plans to move UMTS to 4G speeds of 100 Mbit/s down and 50 Mbit/s up, using a next generation air interface technology based upon OFDM.

As regards market launch, the first UMTS network in Europe was launched by Manx Telecom on the Isle of Man (a large island in the Irish sea) in 2001. Manx Telecom is part of the O2 group, which is now a subsidiary of Telefonica. O2 used the island as a testbed for 3G technology. The 3G service was launched in the UK and Italy in March 2003. To meet this early date, this was a soft-launch with limited coverage of the UK initially available. In February 2004, Vodafone began a wide-scale UMTS launch in several European markets, including the UK, Ireland, Germany, The Netherlands and Sweden, while Greece became a part of this market by mid-2004.

## APPLICATIONS

The deployment of the third generation cellular networks has opened up many new horizons for over-the-air communication and more specifically for distant health care delivery. 3G systems can support higher data rates, thus allowing for a range of new applications. The integration of third generation telecommunication technologies in medicine could prove to be crucial in many aspects of remote provision of healthcare, which communication technologies used to-date (such as GSM or even GPRS) cannot support. Such systems can be used for tele-diagnosis, tele-monitoring and tele-consultation in various fields of medicine.

Thus for example, one of the most important fields of medicine that renders the use of broadband services imperative for modern healthcare provision is that of Emergency Telemedicine; paramedics that attend to accidents don't have the expertise to handle emergency situations. Real time transmission of various physiological parameters of the patients, such as ECG leads, oxygen saturation and blood pressure, between the paramedics of an ambulance and a specialized doctor, either inside a hospital / medical centre or on the move, constitute a significant aid to the doctors in order to guide the paramedics through the process of heart recovery and/or drug provision to the patients (Pavlopoulos & Kyriakou & Berler & Koutsouris, 1998). Apart from the transmission of the physiological parameters of the patients, the paramedics can also acquire and send to the specialized doctors still images or video of the patient. The visual contact is of crucial importance since the doctor obtains a thorough clinical image of the patient. Thus, a specialised doctor can telematically "move" to the patient's site and instruct unspecialized personnel when handling an emergency or telemonitoring case. Third generation cellular networks do not only guarantee the necessary bandwidth for the data transmission, they also guarantee the stability of the flow of the transmitted data. This is achieved due to the "soft hand-over" process, during which the mobile terminal switches from one cell to another in such a way that there is a point in time that it communicates with both cells.

Navarro et al have presented the architecture of a multi-collaborative mobile telemedicine system optimized to operate over 3G mobile networks, with the evaluation results showing a reliable performance over IPv4 UMTS access (Navarro et al, 2005). Encouraging are also the results of the experimental evaluation in terms of various performance metrics such as frame delay, jitter, frame delivery ratio and interframe interval, of a mobile tele-trauma system, capable of simultaneously transmitting video, medical images and ECG signals over real 3G network conditions (Chu & Ganz, 2004). Other scientific approaches that could be enhanced through the use of 3G cellular networks as regards emergency telemedicine include the wireless telemedicine project from the University of Maryland (Gagliano, 1998), the European Union's Ambulance (Pavlopoulos et al, 1998) as well as the British Lancashire Ambulance (Curry & Harrop, 1998), which all utilized the GSM cellular network. The same applies for the scientific approach of Xiao et al regarding the design of a telemedical system for ambulance support (Xiao et al, 2000). In addition, other telemedical approaches that are not however bandwidth demanding, can also benefit from the advanced features of the 3G cellular systems. Such are for example the cases of Karlsten et al, Anantharaman et al, Rodriguez et al and Istepanian et al (Karlsten & Sjoqvist, 2000) (Anantharaman & Han, 2001) (Rodriguez et al, 2001) (Istepanian et al, 1999).

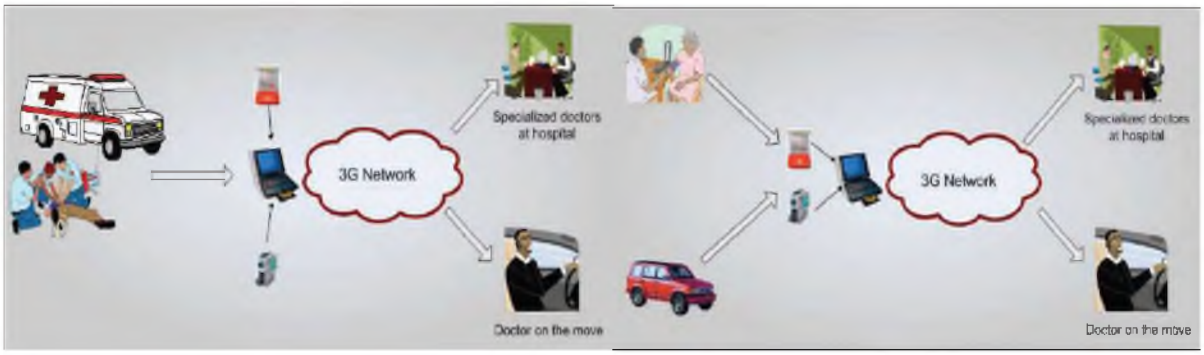
Apart from emergency telemedicine scenario, 3G telecommunication networks can ease tele-consultation in fields of medicine requiring transmission of high definition still images, such as dermatological Images, X-Ray Images, Magnetic Resonance Images, Ultrasound Images and Computed Tomography; scenarios comprising transmission of still images include tele-radiology, tele-ophthalmology, tele-dermatology, tele-dentistry and more. It is a known fact that the high resolution of these images produces heavy payloads of data when they are to be transmitted. For doctors inside or outside of the hospital area (among doctors of the same hospital or doctors situated in hospitals scattered wherever 3G communications are available), the knowledge sharing and distribution amongst them as regards diagnosis is significantly helpful.

Studies have proved how time-saving and thus effective the utilization of 3G networks (as compared to GSM and GPRS) can be, in terms of transmission time, throughput and network utilization (Perakis et al, 2005). GSM and GPRS networks, due to their lack of broad bandwidth availability, render the transmission of such payloads inefficient, almost impossible. Yet, 3G cellular networks have minimized the time required for the transmission of such images, reducing them up to a ratio of 8 times. Nevertheless, the GSM network has been utilized for the transmission of medical images. Such is the case of the transmission of CT images for tele-consultation proposed by Reponen et al (Reponen et al, 2000). 3G networks can also substitute satellite systems, as the ones proposed by Stewart et al, Takizawa et al and Yogesan et al for the transmission of medical images in the fields of tele-radiology and tele-ophthalmology (Stewart et al, 1999) (Takizawa et al, 2001) (Yogesan et al, 2000).

Nevertheless, it is in some occasions imperative that real time video needs to be transmitted. This situation is very common – and yet crucial – in cases of accidents where the patient's body has been heavily injured, and the conveyance of the patient from the place of the accident to the ambulance and respectively to the hospital requires delicate movements. It is obvious that real time audio-visual communication with the expert doctor is imperative. The visual contact is of vital importance since the transportation of the patients can lead to severe nerve injuries that can – and should - be avoided. It is a known fact that only specialized medical personnel should be in charge of accident victims' transportations. In the case the specialized doctor is inside the hospital, the tele-consultation takes place via fixed (high speed internet, xDSL or hospital LAN) or wireless networks (hotspots inside the hospital). In the case the specialized doctor is on the move, 3G cellular networks can be utilized by both parties. It is obvious that this can put extra strain to the network, yet the bandwidth is sufficient for bi-directional videoconferencing. This video-conferencing capability could also be very helpful in the case of an echography examination, as proposed by Ribeiro et al in 1999 (Ribeiro et. Al, 1999). Video-conferencing over 3G networks and more specifically transmission of ultrasound medical streams over 3G networks have also been evaluated during the OTELO project, as analyzed in the forthcoming paragraphs (Garawi et al, 2006). 3G networks do not only grant users with the necessary bandwidth for the video-conferencing (studies have concluded that for acceptable video-conferencing sessions, at least 2 ISDN lines which equal 128 kbps are required), but they also diminish frame losses due to the "soft hand-over" process.

Last but certainly not least, another field of medicine that requires continuous monitoring of patients, which can be enhanced by 3G broadband services but are not nevertheless critical in this situation is that of homecare. For patients with

*Figure 3a. Emergency Telemedicine Scenario*




chronic diseases, continuous monitoring of critical data (Glucose measurements, Invasive and Non-Invasive Heart Rate (instances of hypertension), Saturation of Oxygen and other arithmetic data) can be both life-saving and self-assuring for the patients. Even in the cases of pregnant women, the continuous remote monitoring of both the mother's as well as the baby's medical data are crucial. Patients that are being monitored on a daily basis can be granted with complete freedom of movement and can pursue a normal everyday life. With continuous monitoring, the treating doctors have more and timely information as regards the patients' conditions and are able to provide better advice and suggest better treatment.

Several research approaches regarding homecare have been considered. Woodward et al have proposed the use of a telemedical system comprising a mobile telephone with sensors for patient monitoring, with the modular design of the system enabling telemedicine providers to adapt future mobile 3G standards (Woodward & Istepanian & Richards, 2001) (Istepanian, & Woodward & Richards, 2001). He has also described the modular design of an interface and processor for the transmission of multichannel biomedical signals over a Bluetooth to GPRS-based mobile cellular networks (Woodward & Rasid, 2005). Johnson et al have proposed the use of a wireless cardio-respiratory telemonitoring system for in-home use, while Mendoza et al and Elena at al have provided for heart-failure patients (Johnson et al, 2001) (Mendoza & Tran, 2002) (Elena et al, 2002). All these attempts could significantly boost their capabilities and services with the use of 3G cellular systems.

It is obvious that third generation communication systems are not only useful among paramedics and specialized doctors. They can be applied in a number of other incidents. Thus, they can be applied in organized extreme sport events, sports medicine and much more. After all, the market for para-health services and applications such as physical state monitoring during sports training is becoming increasingly common. Two scenarios, graphically illustrating the aforementioned mentioned scenarios are depicted in figures 3a and 3b. Figure 3a illustrates the emergency telemedicine scenario, where the paramedics can utilize a laptop combined with a 3G PCMCIA network card and a digital camera (or even a mobile phone with a high resolution VGA camera) in order to establish video-conferencing sessions with the specialized doctors and/or send images of the patients as well as screenshots of the medical equipment connected to the patient. Figure 3b illustrates the scenario of homecare and chronic disease management scenario.

## RELATED RESEARCH

A plethora of research projects have either utilized and evaluated the 3G cellular networks, or have provided for their utilization. Apart from those however, various other projects could benefit from the advanced characteristics of 3G networks. For example, the **WardInHand** project (IST-1999-10479) allowed the management of key clinical information while providing decision support to mobile medical staff (Virtuoso, 2006). It provided a tool for workgroup collaboration and wireless access to the patients' clinical records. Thus, the medical stuff of a medical ward could make use of the system through the hospital WLAN, whereas during home visits fast and secure access could be granted via the 3G cellular networks.

The **TELEMEDICARE** (IST-1999-10754) incorporated advanced and reliable sensors on the body that supplied high quality medical data which were sent to the patient's computer through wireless communication (CORDIS: TELEMEDICARE, 2007) (TELEMEDICARE, 2007); the prize-winning **TeleInVivo** project (European Commission Telematics Technologies Program Project #HC4021) aimed at setting up a transportable telemedicine workstation, integrating in one custom-made device a portable PC with telecommunication capabilities and a light, portable 3D ultrasound station (TeleInVivo, 2007) (Kontaxakis & Sakas & Walter, 2006).

The **DOCMEM** project (IST-2000-25318) targeted ambulatory and in-hospital medical doctors and offered them an advanced interactive environment for getting a ubiquitous, permanent and intelligent access to patients' medical files. The work performed aimed at ensuring that the DOCMEM services were accessible through E-GPRS and would be scalable to UMTS networks (Eddabbeh & Drion, 2006).

The **Mobi-Dev** project (IST-2000-26402) constituted a European effort which addressed the increasingly demanding need of health professionals to effectively, accurately, securely, from anywhere, anytime and in a user-friendly way communicate with patients' databases located within hospitals, private offices, laboratories or pharmacies (CORDIS : Mobi-Dev, 2007). The Web Mobi-Dev, one of the outcomes of the project, consisting in an Internet-based wireless mobile system with speech understanding capabilities, corresponded to the project's original objectives, with the exception of UMTS support, that was not fully tested since this technology was still in a pre-commercial stage at the end of the project lifetime. Nevertheless, the supported UMTS connection permits the use of the system for transmitting large amounts of data (Mobi-Dev, 2007).

The **Healthmate** project (IST-2000-26154) contributed to the definition of a new generation of GPRS/UMTS portable personal systems (CORDIS : HealthMate, 2007). The project developed four tele-care innovative platforms to cope with a large number of potential client groups and health needs, also providing for UMTS interoperability, even though the UMTS networks were not available at the beginning of the project. Among the project objectives was to prioritize the continuity of care using the roaming capacity of GPRS and UMTS to move seamless from home cells to macro cells adjusting data rate on demand. As conceived, high bandwidth would permit to accomplish some features that were not possible with 2nd generation mobile telephony services (HealthMate, 2007).

The **AMON** project (IST-2000-25239) aimed to research, develop and validate an advanced, wearable personal health system that would monitor and evaluate human vital signs using advanced bio-sensors. The system gathered and analyzed vital information - including HR, 2-lead ECG, BP, SpO2, skin perspiration and body temperature - and transmitted the data to a remote telemedicine centre, for further analysis and emergency care, using GSM/UMTS cellular infrastructure (CORDIS : AMON, 2007). While first prototypes had problems with achieving the required medical accuracy on all the measurement, the tests have provided a clear indication of the feasibility of the concepts and validity of the solutions adapted by the project (AMON, 2007).

The **MobiHealth** project (IST-2001-36006) aimed at introducing new mobile value added services in the area of health, based on 2.5G and 3G technologies, through the integration of sensors and actuators to a Wireless Body Area Network (CORDIS : MobiHealth, 2007). These sensors and actuators would continuously measure and transmit vital constants along with audio and/or video to health service providers and brokers. A first objective of the MobiHealth project was to prove the advantages, the usefulness and the feasibility of the use of 2.5G and 3G infrastructures in e-health. Evaluation testing in 2003 showed the stability and effectiveness of the MobiHealth system as well as the feasibility of it being used in a wide range of medical fields (MobiHealth, 2007).

The **MOEBIUS** (Mobile Extranet Based Integrated User Services) project was an FP5 European Funded project, the objective of which was to develop a platform for remote access to intranet services using mobile access technology and investigate its performance characteristics to demonstrate the advantages for health care and business applications (MOEBIUS, 2007).

The **WEALTHY** "Wearable Healthcare System" system integrated computing techniques, smart sensors, portable devices and telecommunications, together with local intelligence and decision support system (WEALTHY, 2007). The system would assist patients during rehabilitation or subjects working in extreme stressful environment conditions ensure continuous intelligent monitoring. Smart material in fibber and yarn form endowed with a wide range of electro physical properties (conducting, piezoresistive, etc) were integrated and used as basic elements to be woven or knitted in fabric form. The simultaneous recording of vital signs would allow parameters extrapolation and inter-signal elaboration that contribute to make alert messages and synoptic patient table. The main objective of WEALTHY was to set up a wearable healthcare system that would improve patient or user autonomy and safety.

The **OTELO** project (IST-2001-32516) proposed the study and development of a fully integrated end-to-end mobile tele-echography system for population groups that were either temporarily or permanently not served locally by medical experts (CORDIS : OTELO, 2007). OTELO was a portable ultrasound probe holder robotic system, supported by mobile communications technologies, that reproduced the expert's hand movements during an ultrasound examination. The authors concluded that such advanced robotic m-health systems can successfully perform using commercial 3G networks [30]. In addition, 3G wireless communication technology can provide a cheaper and more convenient mobile medical service for the OTELO system.

The eTEN project **C-Monitor** (eTen-C27256) aimed at market validating a telecommunications platform for monitoring non-hospitalized patients, through which the patient could actively participate in his disease treatment and the doctors could monitor the disease condition of the patients more convenient, more flexible and change the treatment plan quickly based on the information acquired from the patients (CORDIS: C-MONITOR, 2007). Mobile patients and mobile physicians could interconnect through mobile networks, and be granted with the ubiquitous advantages, roaming capacity and seamless communication the UMTS could provide, along with higher data rates (C-MONITOR , 2007).

Furthermore, the eTEN project **LinkCare** (eTEN-C517435) aimed to market validate competitive services with a view to link health professionals in emerging care environments, incorporating 3 pilots, namely HCPB in Spain, CNRHA in Norway, and LITO in Cyprus (CORDIS: LinkCare, 2007) (LinkCare , 2007). The Cypriot pilot was based upon the project DITIS and is an Internet (web) based Group Collaboration system with secure fixed and mobile (GPRS/GSM/WAP) connectivity, that can greatly benefit from the 3G cellular networks. The system supported the dynamic creation, management and co-ordination of virtual collaborative medical teams, for the continuous treatment of patients with chronic diseases at home and specialist healthcare centers (Pitsillides et al, 2005). The Spanish pilot on the other hand was based on the Chronic Disease Management Model for COPD patients. The system integrated two main elements, the Chronic Patient Management Center and the Remote Access Units (DeToledo, 2002) (Del Pozo 2006). The RAU used by the medical staff during home visits (Mobile Home Visit Units) supported among others ubiquitous access to the chronic patient information database, and in order to communicate with the CPMC they utilized wireless networks (GSM/GPRS).

Other concluded projects that could also benefit from the use of 3G networks include the **MOMEDA**, the **Cardiology-On-The-Move** and the **EMERGENCY-112** projects, which had not provided for the use of broadband cellular networks since they were not available at the time.

## LIMITATIONS

Third generations cellular networks however are not a panacea. According to the findings of Bults et al, services requiring fast, high capacities networks may be hindered by the restrictions imposed by the 3G network's goodput bottleneck and the asymmetric transmission capacity (Bults et al, 2005). The downlink capacity in 3G networks is much higher than that of the uplink, while the reverse is required in monitoring services, since the end-user (e.g. the patient) is the producer of information, transmitting high quantities of data. Val Jones et al conclude that we still suffer from limited bandwidth for some applications, such as those which require serving many simultaneous users with conversational applications requiring high-quality two-way audio and video, or generation of 3D animation in real time (Jones et al 2006). These networks also appear to have drawbacks and limitations, especially as regards their adaptation in the healthcare industry. The high cost of the communications links nearly precludes their use in everyday constant monitoring. Furthermore, the healthcare sector is a very complex industry, difficult to change, while the currently available telemedicine equipment can sometimes be difficult to handle, and thus meet the medical personnel's negative disposition in adopting them (Istepanian & Lacal, 2003). In addition, there is a lack of integration between mobile telemedicine systems and other information systems, while there are not enough numbers of demonstration projects that show mobile telemedicine's real savings potential (Istepanian & Jovanov & Zhang, 2004). Further issues that need to be further evaluated and resolved include the development of even more efficient modulation techniques, the allocation of new spectrum, the provision of personalized services as well as user acceptance issues (Nicopolitidis, 2002).

## BENEFITS

According to the previously stated, we can conclude that the third generation telecommunications systems can can constitute a significant player as regards tele-medical applications. A great benefit to all users will be a more efficient management of medical resources and far greater independence. 3G cellular systems grant the users with flexible and swift access to expert opinion, as well as provide rapid responses to critical medical care regardless of geographical barriers. 3G cellular networks can improve on the one side the life of patients, as well as allow the introduction of new value-added services in the areas of disease prevention. The potential benefits of integrated wireless telemedicine based on 3G cellular networks can be summarized as follows (Tachakra et al, 2003):

1. It provides rapid response to critical medical care regardless of geographic barriers. Hence, severely injured patients can be managed locally and access to a trauma specialist obtained by wireless telemedicine.
2. Flexible and swift access to expert opinion and advice at the point of care without delay and better management of medical resources.
3. Interactive medical consultation and communication links of medical images and video data such as the videophones over Internet links in complete mobility and in global coverage and connectivity.
4. Increased empowerment and management of medical expertise especially in rural and underserved areas could be improved using these technologies.
5. The local hospitals usually do not share care or staff with larger hospitals. Consequently, some may suffer from weak medical and nursing staff who may be uncomfortable managing seriously ill patients.
6. Swift medical care can be made available in emergency and management of medical data in catastrophes or natural disasters where conventional communication links may be disrupted.

## DISCUSSION

Utilization of 3G networks achieve a significant reduction as regards the time required for the transmission of data (biosignals, images and video of the patients) from the side of the patient to the side of the expert. Furthermore, the support of the "soft hand-over" process guarantees the stability of the flow of the transmitted data. Impermanent losses of signals may not be crucial in many real time applications, yet is crucial in cases where healthcare delivery is concerned and human lives are at risk. Nobody can doubt the fact that so far these third generation networks have not met the expectations they were supposed to meet when they were originally conceived. Nevertheless, since the number of 3G cells within every European country will keep increasing much like 2G cells did in the past, utilization of such broadband networks are bound to have an increasingly high field of application and a guaranteed success as more and more areas are covered by UMTS. And since the minimization of the time required for a patient to receive primary care has always been one of the utmost concerns of hospitals, health centers as well as ministries of health, the reduction of this time achieved by such networks is bound to make them an attractive solution.

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