

# WiMAX Supported Telemedicine as Part of an Integrated System for E-Medicine

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**Abstract.** *This paper presents an overview of the wireless telemedicine components of an integrated system for e-medicine that we propose and implement in the Republic of Macedonia. A short introduction to telemedicine and its evolution is presented. The new wireless broadband technologies enabled creation of telemedicine services previously only possible via cable connections. The novel wireless technologies enable provision of advanced medical services to rural areas unreachable by cable connections. WiMAX and Wi-Fi are the technologies used to implement our telemedicine functionalities. They are shortly described and a number of proposed and provided services are explained. Guidelines are given for further development and implementation. The experience gained draws conclusions that can be used in areas or countries with similar natural or economical conditions.*

**Keywords.** Telemedicine, eMedicine, WiMAX, e-Medicine, wireless, e-health, eHealth

## 1. Introduction

This paper presents a part of an ongoing research for designing a prototype of an integrated system for e-medicine. The proposed system would consist of medical information systems (MIS), decision support functionalities, data mining modules and telemedicine functionalities. The system is modular and therefore easily upgradable.

Telemedicine and related healthcare technologies aim to provide efficient healthcare remotely. It ought to improve the well-being of patients and bring medical expertise at a lower cost to people in need at the right time. Wireless telemedicine is a rather new emerging area. The low bandwidth or high costs of previous wireless technologies disabled advanced telemedicine services. Recently, the establishment of

broadband wireless standards like WiMAX (IEEE 802.16) enabled implementation of telemedicine functionalities that were previously only possible with cable links. Wireless telemedicine is especially suitable for areas lacking proper cable connections or places where installing cable links is difficult, economically unviable or simply impossible. For instance, in cases of natural disasters [10], installing wireless links is the only possible way to establish communication and provide medical service.

As a result of the fast development of telecommunication technologies, many telemedicine applications have been developed recently [4,5,8,10,11,13]. Telemedicine has various potential uses such as clinical, educational and administrative. Telemedicine can bring high quality medical service to underserved areas. Experiences [12] show that telemedicine provides a solution to various problems such as: access to care for large segments of the population, reducing healthcare cost, bring experience and expertise closer to patients, solve uneven geographic distribution of service quality. It can improve quality as a result of providing coordinated and continuous care for patients, targeted and highly effective continuous education for providers, and highly effective tools for decision support.

The rest of the paper is organized as follows: Chapter 2 gives the background and evolution of telemedicine, as well as its future perspectives. Our main goals and objectives are stated in Chapter 3. Chapter 4 presents the current situation of e-medicine in the Republic of Macedonia, while chapter 5 elaborates a plan for implementation of advanced e-medicine. The telecommunication network available for this telemedicine project is briefly presented in chapter 6. The implemented system and telemedicine functionalities are described in chapter 7. The concluding remarks are given in chapter 8, followed by references in chapter 9.

## 2. Background and evolution of telemedicine

The evolution and growth of telemedicine is highly correlated with the developments in communication technology and IT software development. This dependency is evident if we review the history of telemedicine technologies. Researches categorize the telemedicine history into three eras [1,12]. All the definitions during the first era of telemedicine focused on medical care as the only function of telemedicine. The first era can be named as telecommunications era of the 1970s [1]. Applications in this era were dependent on broadcast and television technologies. Telemedicine applications were not integrated with any other clinical data.

The second era of telemedicine, dedicated era, started during the late 1980s as a result of digitalization in telecommunications and it grew during 1990s [1]. The transmission of data was supported by various communication mediums ranging from telephone lines to Integrated Service Digital Network (ISDN) lines. The high costs attached to the communication mediums that can provide higher bandwidth became an important bottleneck for telemedicine.

Dedicated era has turned into an Internet era where more complex networks are supporting the telemedicine. The third era of telemedicine is supported by the technology that is cheaper and accessible to an increasing user population [1]. The enhanced speed and quality offered by Internet or 3G mobile telephony [13] is providing new opportunities in telemedicine.

During the evolution of telemedicine, new technologies were developed and the applications and delivery options increased in variety. Application areas expanded to almost all the fields medicine can cover [14].

Since the first formal definition of telemedicine by Bird in 1971, many researchers tried to define this term in order to clarify the boundaries of telemedicine and its use. His definition states that "telemedicine is the practice of medicine without the usual physician-patient confrontation ...via an interactive audio-video communications system". A newer definition states that "Telemedicine is the use of electronic information and communications technologies to provide and support healthcare when distance separates the participants." Even though the essence of these definitions is the same, telemedicine, and hence its definition, evolved

dramatically as a result of the tremendous changes experienced in the telecommunication and information technologies. Newer terms and research areas have emerged (telehealth, e-health). According to Maheu in 2001 [1], E-health refers to all forms of electronic healthcare delivered over the Internet, ranging from informational, educational, and commercial "products" to direct services offered by professionals, nonprofessionals, businesses or consumer themselves. Recent applications of telemedicine include: Consultation, Diagnostic Consultation, Monitoring, Education, Disaster management [10], Virtual Microscopy [4], Homecare, Diagnosis, Treatment and Therapy (Psychology).

## 3. Our objectives and conception

While researchers in developed countries can have different goals, our objectives had to be scalable, ranging from establishment of basic telemedicine services up to advanced up to date functionalities. The main concepts that our system was based on include:

1. Creation of necessary basic Medical Information Systems (MISs) in hospitals;
2. Creating a framework and interfaces where various multiplatform MISs could interconnect in an integrated MIS;
3. Using modern telecommunication technologies for connecting parts of the integrated MIS and provision of advanced medical services at remote locations.
4. Using the integrated MIS for various telemedicine applications (sharing knowledge, experience and expertise among physicians in different hospitals, consultations, enabling better remote patient-doctor communication, and better access to medical information).

## 4. The current state in the Republic of Macedonia

In Macedonia there is no integrated health information and communication system (ICT). There are only individual systems at some of the hospitals. The analysis of the current solutions show significant differences among hospitals, but the overall conclusion is serious lack of ICT. The only exception of the general rule is the Special Hospital for Orthopedics and Traumatology "St. Erazmo" in Ohrid with relatively new computers, functional network and semi integrated hospital information system functioning throughout the

hospital and covering all major workflows. Also, it is evident that information systems that operate in some facilities will be challenging to integrate and extremely difficult to enable information exchange.

The specific situation and circumstances lead to the idea to start a research for developing an integrated system for e-medicine specifically suitable for a developing information society like the one in Macedonia. The research is supported by several PhD and master students working on various components of the system. The result of the research ought to be a prototype for an integrated, but modular system for e-medicine, including medical information systems, decision support, data mining modules and telemedicine functionalities. The prototype should set a basis for further development and upgrade.

## 5. Implementation of e-medicine in Macedonia

The implementation of an integrated e-medicine system in Macedonia should be gradual, but increasingly fast in order to close the gap with the developed world. After purchasing the necessary hardware equipment and software, a crucial step should be adopting unified registries and coding systems for electronic data storage. Electronic health card (EHC) should be implemented. Recent scientific papers even suggest RFID skin implants so the patient can be identified and treated even when unconscious. Thanks to the integrated system, the patient's data will be available throughout the country, and even abroad.

Having set up a solid basis in terms of an integrated medical information system, various telemedicine services could be deployed, and later upgraded along with the growth of technologies.

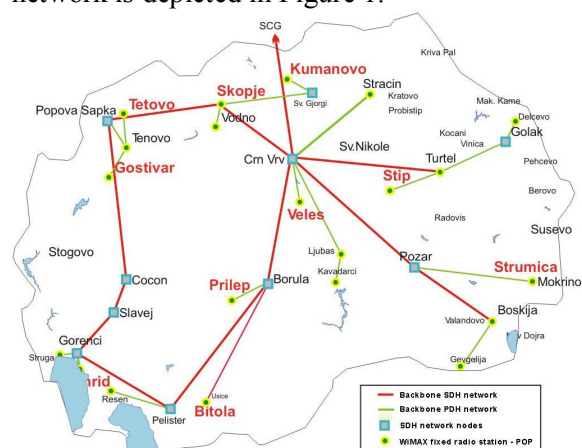
In the long term, the integrated system should implement Diagnosis Related Groups (DRG) after converting the data into standardized Electronic Health Records (EHR). Using data mining techniques, modules will be developed for the integrated system that will serve as diagnosis consultants. Certain data has already been available, like blood tests from 70000 patients in the Ohrid Orthopedic hospital. This data already serves as simulation input in our research where constraint programming and combinatorial optimization is used for drawing medical conclusions.

## 6. Wireless infrastructure

Due to higher costs of fiber optic installation, and the sufficient bandwidth of WiMAX, it is used to cover most of the needs of our telemedicine system. WiMAX is a telecommunications technology aimed at providing broadband wireless data connectivity over long distances. It is based on the IEEE 802.16 standard. The high bandwidth and increased reach of WiMAX make it suitable for providing a wireless alternative to cable and DSL for last mile broadband access.

The telecommunication market in Macedonia has been growing quickly and de-monopolizing. Currently there are several statewide backbone networks operated by various data communication providers. In order to implement our telemedicine system we are using the backbone network of a fast growing privately owned data communication provider. The backbone network consists of some fiber optic connections in the city limits of Skopje and mostly 802.16 (WiMAX) base stations throughout the country.

Hospitals in different cities are (or will be) connected to the network. Antennas are placed on hills overseeing cities, and coverage with the radio signal is good and robust. The backbone network is depicted in Figure 1.



**Figure 1. Scheme of the wireless backbone network in the Republic of Macedonia**

The optic fiber connections are used for provision of fast bandwidth services where possible. The WiMAX antennas are used for connecting hospitals where the optic fiber has not reached yet and 802.11 hotspots are used for wireless devices (PDAs, notebook PCs etc.) The wireless connectivity is used by both medical personnel and patients.

## 7. Implemented services and functionalities

Implementation of telemedicine services is lengthy and practically a never ending process. We are currently at the initial stages where a couple of hospitals are included in the pilot project: The Institute for respiratory diseases in children-Kozle and the University clinical center in Skopje. Due to the lack of a modern Medical Information Systems (MIS) in the hospitals, the project had to start from scratch. We developed the initial Web based MIS to be used by the staff at the Kozle children's hospital. Since the hospital cannot afford to maintain an IT department, the MIS is hosted on the Internet Service Provider's servers. Since connectivity speeds are high enough when using WiMAX, there is no need to host the MIS locally at the hospital. The MIS is developed as a web application that can be accessed by a common Internet browser. The staff at the hospital can browse the MIS, log in using their username and password and access patient's data. The homepage of the web application is presented in Figure 2.



**Figure 2. The web based medical information system in the Institute for respiratory diseases in children-Kozle.**

Querying data in the web based MIS is possible using multiple criteria. Data can be searched from other patients with similar symptoms in order to learn from other previous experiences. Entire patient history is accessible online, with strong regard to privacy issues. While patient identity details are available to the physician in charge of the particular case, for other medical personnel with lower access

privileges, only medical information is available, without disclosing the identity of the particular patient.

A vital part of a telemedicine system is the sharing of knowledge, experience and expertise. The implemented MIS includes a forum and a virtual chat room where physicians can consult each other. Since the children's hospital and the university hospital are connected to the same system, consultations are possible among physicians from both hospitals. The system has an Internet interface toward the outside world where advices can be gathered or given from and to physicians anywhere in the world.

The developed system includes software components specialized for use by PDA devices. Both patients and staff can wirelessly access different software modules. Physicians can access patient's data, results from laboratory analyses, forums and chats, web sites with medical scientific papers. Patients can access their results from different analyses, make appointments, and check the availability of certain physicians.

Initially telemedicine was defined as provision of medical services at remote locations without direct physical contact between the physician and the patient. Our system incorporates modules that enable laboratory results and other analyses to be submitted to review to the specialists. Physicians working in smaller towns can access the system using their accounts and can submit questions along with supporting materials electronically. Special web application software modules are developed for submitting images (MRI, X-Ray, CAT scan) from remote hospitals in the country to the specialist working in the capital. Also results from blood analysis are filled in online forms. Specialists review the results and can post their reply to the sender. This system enables reduction of transport costs, response times are drastically smaller and patients do not have to suffer through long trips to the specialist.

The system includes a Short Message Service (SMS) gateway that is used for SMS notifications for both physicians and patients. Current functionalities include confirmation of appointments for patients, notification for completed laboratory analyses, SMS emergency calls for physicians on stand-by etc. WiMAX is also used for Voice over IP (VoIP) services. PSTN telephone bills are drastically reduced as a result of the use of VoIP for communication among hospitals.

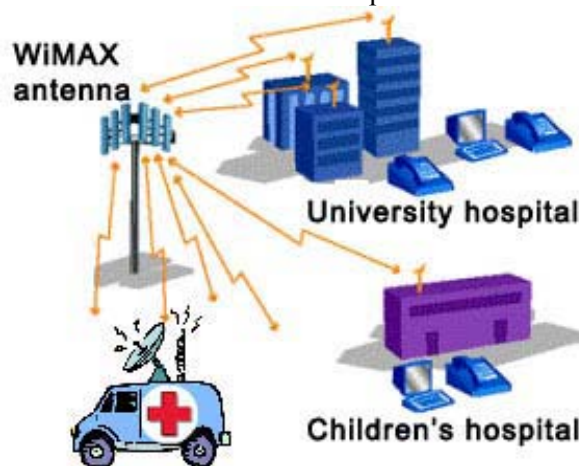
Recent advances in broadband connection speeds have enabled high quality video telephony. In the context of telemedicine, we are testing the use of wireless IP video telephony in communication of patients with hearing impairment. We are using Leadtek IP broadband videophones (BVP8882). They use H.323 protocol for high performance and good quality video communication. The quality of the video stream using only 256 Kbit/s was sufficient for the common sign language to be used and understandable by the communicating parties.

After establishing basic telemedicine functionalities within the capital – Skopje, the next step is connecting the Special Hospital for Orthopedics and Traumatology "St. Erazmo" in Ohrid, in south-western Macedonia. The hospital already operates one of the most advanced MIS in the country. One of the system challenges is integration of the current MIS in Ohrid with the newly developed in Skopje. However, with the use of XML and Web Services, helped by the fast connections of WiMAX, initial results are promising. Since the hospital is situated about 170 km from the capital, Skopje, traveling is often a problem for patients in critical condition. We already tested streaming video through the WiMAX connections and the next step is to enable experts from Skopje to oversee complex surgical operations performed by the surgeons in Ohrid specializing in traumatology and orthopedics. Similarly, students at the University hospital in Skopje will be able to learn from the live feed from surgeries at the specialized hospital in Ohrid. On the opposite side, experts in the Ohrid hospital can offer advice to colleagues in Skopje over specific interventions performed only in Ohrid. Tested speeds promise high quality video.

We performed a video streaming experiment using a vehicle equipped with a WiMAX antenna and an MPEG coding device. We established a continual video stream that could be used to transmit live feed from the patient in the ambulance to the hospitals. The video link enables specialists to give advice to first aid workers on the scene of an accident, based on real time video feed from the patient's condition. Paramedics could be supervised by experienced medical personnel while performing necessary life support interventions. Due to current limitations of WiMAX, the ambulance must not move while being connected online, however new equipment based on Mobile WiMAX (802.16e-2005) is expected to overcome this

issue. The equipment used in the experiment was SCOM MPEG-2 Digital Video Encoder/Decoder. The used WiMAX antennas support 2-10 Mbit/s. The particular experiment used 2 Mbit/s, but an acceptable video quality is achieved even with a 512 Kbit/s connection. Another experiment was conducted using a personal computer instead of a specialized MPEG coding device; however a noticeable delay was evident in the video stream. The later architecture is applicable for a smaller spectrum of services.

The video signal that we used in most of the testing originated from a digital video camera. Another, even more important feature is streaming of digitalized video signals received from analogous endoscopy equipment. We worked on digitalization of an analogous signal from a fluoroscopic camera using a Plextor MPEG encoder. The digital output from the encoder was easily streamed. The received live video could be used to consult subspecialists not present at the location where the exam is performed. Using VoIP and chat on PDA devices, the specialist could provide feedback and guidance to the person performing the exam in the field or in the remote hospital.



**Figure 3. Schematic view of the video streaming experiment.**

## 8. Conclusion

The growing information society in the Republic of Macedonia has a long way to go before it could compete with developed countries. E-medicine follows step along with other growing IT areas. However, the framework proposed in this paper and the steps already taken to implement it promise a fast trip toward a modern system that could enhance the quality of

medical services, reduce costs and increase patients satisfaction and health.

Specific circumstances in the Republic of Macedonia enforce the use of wireless technologies for various applications. Modern wireless telecommunication technologies like WiMAX enable the provision of telemedicine services to places previously unreachable by landlines. New telecommunication technologies that emerge constantly and the development of software enable implementation of novel telemedicine services that were previously only imaginable. Web services and XML enable integration of various Medical Information Systems into an Integrated System for E-Medicine. High bandwidth and reliability of WiMAX helps the integration with bringing remote hospitals ever closer.

Experiences gained in this project could be useful in countries or areas where conditions are similar. The mobility and quick deployment offered by wireless communications will help change our former views of the medical treatment in general, enabling high quality health service remotely and inexpensively.

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