Telemedicine: Healthcare Service Based on ICT

Healthcare Service Based on ICT: the eHealth8 Telemedicine System

(Design Studies Paper)

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Abstract - Telemedicine is a tool of healthcare (and education) based on telecommunication and information technology (IT), where the scene of patient and care (diagnosis/therapy/monitoring) are separated in time and/or place. This article discusses the concepts and design of a telemedicine system developed within the framework of the project implemented by the eHealth8 consortium, first of all with focus on its architecture and communication solutions.

I. INTRODUCTION

The idea of performing medical examinations and evaluations by means of telecommunication networks is not new. Shortly after the invention of telephone, experiments have already been started to transmit heart and lung sounds but transmission capabilities have always arisen an issue. Some recent applications are as follows.

International Virtual e-Hospital, Kosovo

Four telemedicine centers were established during a two-year working period. Telecommunication infrastructure was set up that enabled major medical institutions and medical universities to establish wideband telecommunication connections with each other and with the outside world. Telecommunication connections and Internet are being used both in active medical care and education usually by means of ordinary Internet technologies (e-mail, web, wiki, Skype, Groove etc.). The system includes applicable solutions about the usage of open source Internet standards. Open connection of general purpose elements (e. g. Skype), and the realized solutions suitable for operation in heterogeneous manufacturer environment were useful for the work of the Consortium.

Emergency Telemedicine Applications

During the evolutional process it can be observed that only the minimal amount of the necessary data collecting and communication devices are deployed on site, then analyses and professional intelligence services are provided from remote locations by means of data communications. This way professional knowledge of the centers can be utilized everywhere.

It is very useful that the technology of applying unified decisions made from a geographically remote location. Especially, special, differentiated devices have been set at patients' homes that report on the same communication channel, in the same form to decision makers.

Hungarian Atomic Energy Authority (HAEA) – Nuclear Emergency Response Case Management Support

HAEA is an administrative authority controlled by the Hungarian Government, commissioned with independent tasks and empowered with official rights. Its duty is the official supervision of safe utilization of nuclear energy; especially the safety control of nuclear plants and materials, and the prevention of nuclear proliferation; in addition cataloguing documents in a consistent system. The workflow based on documents and detailed documentation are worth to mention in this study. Also the methodology of tracking and automatic developing of frequently changing processes.

The Role of Service Oriented Architecture in Telemedicine Healthcare System / B&M

Due to the great diversity of devices and manufacturers, the most significant challenge in telemedicine projects is their interoperability. It is difficult to develop a system with properly flexible data exchange among different systems without restricting the groups of data processed. Numerous solutions exist but all of them aim the same from software development point of view. The DICOM system of B&M Company is a typical representative of this tendency. The utilization of SOA architecture, the outsourced expert pool, marketable, commercial off-the-shelf components and ASP function capability also should be noted from this project.

DISPEC TeleTriage and Dispatch System

The Bucharest Ambulance Service (SAMB) functions as an independent organization, and serves 2.5 million people. Beyond emergency care service its tasks are to provide home care in difficult cases, event control, organ, blood and medicine transportation, moreover issue of official certificates. The experiences of practical establishment of return calculations and utilization of pieces of experience accumulated in databases.
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- above all the existing technology-based attitude instead of a complex approach considering other aspects of telemedicine introduction and successful long-term utilization, operation.

Successful utilization of telemedicine systems in the long run that brings real benefit for all participants is possible only if these impeding factors are eliminated. The eHEALTH8 consortium of medical, IT, economic and measuring technique experts was established in 2008, in order to design a telemedicine system that is remunerative for patients, society and care system and develop its infocommunication and economic system.

Members of the consortium are, in alphabetical order, Answare Ltd. Bay Zoltán Foundation for Applied Research, Humansoft Ltd., Semmelweis University, Thormed Ltd.

The members of the consortium have prepared a project proposal to implement the tasks mentioned above, that was granted by the National Office for Research and Technology (NKTH) ‘Lifestyle supported by infocommunication devices’ (AAL – Ambient Assisted Living) subprogram. The objective of the project was to establish the IT and medical basis and construct the prototype of a telemedicine service system that does not rely on presently available, separately operating telemedicine sub-processes but focuses on rearranging medical protocols on the basis of domestic and international experiences. By extending towards telemedicine the project makes efforts to apply protocol-based approach that fits in new, already existing medical therapeutic directives during the design of IT support of telemedicine processes and the development of services.

In order to increase the growth potential in efficiency as much as possible, protocol-based approach is supplemented by cost efficiency and feasibility study. The objective of this activity is to highlight application areas and processes, which are likely to result in the most considerable efficiency growth rate and/or cost reduction for the participants of healthcare service and/or financing system while achieving the same level of individual health benefits or higher.

The eHEALTH8 project emphasizes the support of doctor-patient relationship within telemedicine. Fundamental requirements for the presently developed system are aimed at eliminating the deficiencies of current telemedicine systems mentioned above; moreover expectations that are beneficial in the domestic medical care environment are drafted:

- the system of devices and processes developed need to be based on medical protocols approved by medical profession;
- the system of devices and processes developed should bring the highest level health improvement for the patient;
- it should be simply extendable with measuring processes, examination and nursing protocols without any changes in the central base system but supported by its functions;

II. THE eHEALTH8 PROJECT

In spite of the fact that utilization of telemedicine – in addition to its necessary application in certain cases –, can result in more efficient operation of health care systems and in decrease of the employment of expensive and scant resources, it is less widespread than expected. The fact that technologies for telemedicine applications are available and there are numerous successfully implemented experimental pilot projects – though in many cases only in order to separately check and analyze the medical effectiveness of new technologies – urge the spread of telemedicine. However, there are several factors that present hurdles in the way of wide penetration of telemedicine:

- lack or poor quality of economic models, case studies, analyses that supplement available medical evidences,
- lack of structured processes of medical evidences available in certain fields and their integration into medical professional directives, protocols that are the basis of medical professionals’ approval and availability of financial resources as well,
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- it should ensure mobility and as extended independence for patients as possible during different medical treatments;
- it should have the capability to connect to the inter-institutional information systems established in HEFOP 4.4;
- it should be applicable to preventive (status and lifestyle assessment) and aftermath care purposes.

III. THE ARCHITECTURE AND COMMUNICATION SCHEME OF TELEMEDICINE SYSTEM DEVELOPED BY eHEALTH8

The architecture (Figure 1) includes the main participants and the directions of service flow. The protocol service provider uses professional support of the protocol expert to interpret, assess the application and maintain the protocol itself. The telemedicine service provider also resorts to medical, health care supplier, technological and logistic service background. The figure demonstrates that patients can use service at least three ways: (i) within the framework of a health care service, (ii) as a fitness, wellness, sport, leisure activity or (iii) as an independent health surveillance or management service.

BASIC REQUIREMENTS FOR PATIENT SIDE INTERFACE

Telemedicine methods do not simply mean the utilization of traditional methods the way healthcare assistance is performed by patients or their surroundings. Complying with the rules regarding to the measurements requires self-disciplined, conscious behavior of the patient. In case the rules are disregarded but the measurement is performed, measured results will not be real values and the therapeutic decisions based on measurement will not bring the expected result.

Elderly people need a special unit which enables simple use, possibly with the simplest and most robust design. Due to weakened visual capabilities, large, in some cases extra large display is needed with an audio unit. Any data recording can be problematic due to trembling hands. Usually patients are afraid of busting up the devices they handle, so persistent, motivating education and training is a priority for them. Regular feedback and knowledge update are necessary during personal visits. In their case devices must contain instant emergency call function, too. Traditional medical devices were not designed in a way to enable the patients to use them on their own. The patient is a participant of measurement and intervention but the operator of the device is always a physician or medical professional. Measurement results are analyzed by a professional who decides if the result is within the expected range, i.e. whether it can be valid at all or the result of the measurement is false, loaded with disturbance, or the behavior of the patient could have an effect on it. During telemedicine processes it is not always possible to validate the way that focuses on selecting the right method and the autonomic validating and pre-evaluative functions of the examining system.

Examinations must start with identification of the patient in every case, so (theoretically!) it is impossible that another patient’s measurement data are recorded in someone’s documentation. Identification is of special importance during a telemedicine application when patients are not present at the site of healthcare provider but they are e.g. at their homes, where anyone who can have an access (e.g. family members) can use the device, even can substitute the patient. Another essential problem is how it can be stated with responsibility that the results of a measurement performed at a patient’s home are acceptable, were created under the right conditions that are determined by measurement protocols, thus the medical decisions can be based on them. Fundamental precondition of telemedicine utilization is to solve the identification of the patient with a safety level corresponding to the cost of measurement or to the extent of possible damages caused by deliberate or accidental misidentification.

![Figure 1: Service model of the eHealth8 telemedicine system](image-url)
Currently available technologies—based on ownership, special and biometric information—make identification possible in various ways:

- ownership
  - RFID identification
  - bar code
- biometry
  - fingerprint identification
  - retina identification
  - based on typical characteristics of the individual of the examined parameter (e.g., exhaled breath)
- special knowledge
  - password (PIN code)

The utilization of these methods and combinations make different levels of reliability in identification possible.

At present, most of the currently available devices do not have any identification facilities so the patient is responsible for the origin of the measured values. The objective of the utilization of these devices is not to supplement the tele-monitoring system as an interface on the patient side but support patients’ self-check. From a technological point of view, the correct solution could be fingerprint identification or an RFID chip implanted under the skin or worn on a bracelet used together with a reader built into the device. Taking into consideration the characteristic of the currently supported applications, development costs, and applicability, at present fingerprint identification is practical to be accomplished.

To sum up, the main requirements for patient side devices are as follows:

- safety and reliability:
  - operation:
    - do not require installation performed by experts as far as possible;
    - the device should give information automatically on its technical condition to the centre (self-test);
    - its basic maintenance (recharge or replacement of battery) should be simply performed even by the user;
    - it should be possible to remotely update the device’s firmware
  - data transmission:
    - expected reliability of data transmission and patient identification should be

adjusted to sensitivity and risks of the telemedicine process;
- in case of using public data transmission networks, data transmission has to be protected from accessing by a third party;
- data consistency has to be ensured from measuring device to the centre;
- ergonomics – surfaces, utility procedures:
  - measuring unit should be suitable for independent measurements performed by the patient;
  - it should be easy-to-use, mounted by as few operation buttons as possible;
  - patients should get constantly available information on the specified method of measurement (automatic audio, video comments – downloadable or displayable on the device – chart of a few pictograms etc.).
- bi-directional communications that should work not only in the patient -> telemedicine centre direction but also in the opposite direction, including the communication from the physician towards the patient through the centre.

IV. AN OVERVIEW OF THE ARCHITECTURE (SERVER, CLIENT-SIDE CENTRE, END POINT DEVICES / SENSORS), ROLE OF COMPONENTS, COMMUNICATION AMONG THEM

Vast majority of telemedicine centres implemented worldwide including those in pilot stage are self-developed (or are derived from a small range of suppliers). The advantage of this solution is that the data communication protocols of devices are known, further development of device’s functions can be easily realized thus this model can be considered as optimal during the development phase. In case of business model of extended range that covers more groups of chronic diseases, devices have to be selected from a more extensive range of manufacturers; due to the lack of mass production the costs of self-developed devices are usually high, their support is usually weaker than those of on the market. For these reasons it seems to be practical to develop an architecture, in which self-developed measuring devices and constantly wearable sensors take place but devices of a third manufacturer are also applicable in the system. In this latter case the project aimed at implementation
of devices that accept the recommendations of Continua Health Alliance for standardized communication connections. Measuring instruments (end point devices) are always in contact with the Homecare Central Unit (HCU). HCU processes and transmits the received data to the telemedicine centre. Also the HCU provides communication connection between the patient and the medical staff.

**a) End point devices and their communication**

The main measuring devices used for telemedicine processes developed in the project are the followings: body weight scale, blood-pressure monitor, oxygen saturation meter, activity sensor, fall sensor, tremorometer, ECG and spirometer. Different potential solutions were examined during the design phase of devices suitable also for home applications; among others MMS-based and then SMS-based data transmission that are able to establish teledoctor communication cheaply and simply by means of Bluetooth mobile phones. Efficient database solution was developed for data storage that provides sufficient storage capacity at reasonable costs for storing measured data by means of cheap SPI flash memories, while adjusting to the properties of those (e.g. equal distribution of sector employment).

An example for the use of the short message based telecommunication method is the SpiroTube Mobile Edition home care spirometry system with the ThorSoft Mobile Edition interface software. The secret of success with short messages in telemedicine is efficient encoding and data compression. Spirometry results can be stored in a relatively small data space, the most frequent measurement results, that the FVC curve can be stored in one simple SMS with a minimal data loss. The SpiroTube Mobile Edition device can also send the raw respiratory flow-volume signal in real time via Bluetooth to virtually any base station, including the OKE system developed by the Zoltan Bay Foundation. The OKE system can run the spirometry data processing software, based on an extracted library that facilitates communication with the terminal device.

During the system design phase efforts were made by the technical experts of the project to achieve high level reliability and low cost of operation. There are two ways to realize these objectives. On the one hand we should avoid the use of devices that can only be installed by professionals (movement sensors fitted on walls etc.); on the other hand in case of located devices every effort has to be made to provide remote management. This can be achieved for devices developed by the consortium (HCU and end point devices) but unfortunately not for products on the market.

**b) Homecare Central Unit (HCU)**

Special requirements related to certain age groups have already been outlined in the description of requirements for devices section. In order to fulfill the demands of all three groups and to decrease costs by the exploitation of already available devices (computers, mobile phones) of user groups, HCU has been developed in three different ways. Besides the installed device with full functionality, a web-based, virtual HCU has also been developed that can be accessed through a web browser with functionality decreased to a certain extent but available for considerable parts of the juvenile and middle-aged groups. Data provided by the measuring units are received by the virtual HCU via Bluetooth connection of the mobile phone or the computer. The soul of the located HCU is an iGEP V2 embedded controller, to which end point devices are able to connect via USB, Bluetooth and ZigBee. The system is able to communicate with the telemedicine centre by both Ethernet network and GSM modem. The base unit consists of three high-intensity LED-s and three press buttons but it is able to provide appropriate sized image for dim-sighted patients by a pico-projector connected to its VGA port. In case of projected image, navigation can be performed by simple movements of hands ignoring positioning difficulties that occur due to trembling hands. Patient identification is performed by the device on the basis of PIN code and/or fingerprint identification.

Main characteristics and functions of the unit are as follows:

- communication with the telemedicine centre (Oracle BPM server (SOAP));
- communication with end point devices (ZigBee, Bluetooth, Continua);
- patient identification;
- measurements scheduled on the basis of measurement plan determined in the protocol by the telemedicine centre and customized by the physician and initiated by the patient
  - launch;
  - receive and pre-process data;
  - transmit data to the telemedicine centre;
- providing audio and video connection;
- running and displaying applications
  - filling in forms;
  - tests.

**c) Telemedicine Centre**

Utilization of telemedicine processes in healthcare can contribute to their more efficient accomplishment in total: utilization of expensive medical resources can be decreased; meanwhile
beyond preserving efficiency level of treatments value creating ability of active population can be increased by decreasing the amount of wasted working hours; moreover quality features of care experienced by the patients can be improved. In order to realize the positive effects mentioned above, we must have **process and device systems** that fit to new methods and fulfill the requirements (security, reliability, ergonomics etc.) mentioned in the previous chapters at system level.

One of the central elements of the eHealth8 project was the development of the processes (telemedicine protocols) that determine the methods and rules of telemedicine applications within the given professional field for particular groups of diseases. Beyond the fact that accurate application descriptions created this way contribute to more carefully considered and more efficient utilization of resources; they play key role in telemedicine because accomplishment of virtual patient-physician relationships separated in time and place is unimaginable without prior, detailed determination of its rules. Benefits expected from the utilization of telemedicine processes can only be realized if processes are controllable in accordance with the previously determined rules. So system level requirements concerning to the central system described in the previous chapters are supplemented by new ones. The most important new requirements are:

- support standardized representation of telemedicine protocols that enable their unambiguous IT interpretation and processing;
- support controllable and safe performance (run) of telemedicine processes;
- medical professional regulations and realization in running environment have to be accessible at user level too (not only for the software developer);
- ability to get complied with the protocol rules and give quality assurance from the centre as well;
- concerning a given protocol, the ability to easily change the type of measuring device, integrate new ones;
- since telemedicine service is a part of the care process; the ability for appropriate data transfer with in- and outpatient management systems;
- due to data exchange the obligation of long term storage of data (legal state) that is not allowed to be performed in the centre;
- endpoint devices and HCU are connected to the centre via Internet, high level of safety and reliability without the need of any technical assistance are fundamental.

Standardized representation and IT interpretation focus on knowledge share and portability; partly in case of separately developed systems, partly among special medical and IT fields. Endpoint devices do not connect directly to the centre; they receive data solely through the HCU. Consequently HCU accomplishes direct, individual physical attachment of different endpoint devices to the system. The telemedicine processes running in the centre control the endpoint devices through an abstraction layer provided by the HCU; so they have to be made independent from particular types of devices. This architecture provides simple integration of new devices and device independency of protocols. HCU-s communicate with the centre via Internet (mobile or wired), by SOAP calls, standardized XML messages. Even if many components of the system (centre, CHU or the device itself) are able to operate autonomous operation and to make decisions on different levels during measurements, where are data evaluation and making decisions practical to perform? Pre-processing of data is performed on device and CHU level. The CHU downloads technical and physiological threshold values typical to the particular measurement. Evaluation for these values is locally performed as values beyond threshold values can refer to false measurement or device failure, so in any case repetition of measurements is necessary in order to decrease and validate the number of false values. However, the evaluation regarding every process runs in the centre that is important regarding to quality insurance, as the entire sequence can be tracked and audited at the same place.

V: EFFICIENCY AND BUSINESS MODEL

The project is currently considering the possibilities of the integration into the present healthcare financial system. In accordance with its original objective, the project intends to support methods that are the most economical for the patient, the employer, the national economy, the society and the care system in total and/or result in improvement of quality of life for patients. This does not exclude the possibility that its particular cost elements are more expensive but it is a more economical solution in total.

According to the economic model, the telemedicine service provider is a participant of the care system. Basically, the new methods developed on the basis of telemedicine for the community by the care system create new values; therefore the expenditures of value creation can be covered by them. In this respect the telemedicine service provider is an element of the system. Theoretically the equivalent of benefits (profit) created in the system can be transferred to value producers.
different way, as there exist relationships among participants at different levels and of different nature.

VI. SUMMARY

During project implementation the consortium examined thirty different medical professional guidelines; from these guides three telemedicine protocols were developed by the cooperation of medical and technical experts. On the basis of economical considerations, three actual realizations were performed in this project (asthma diagnostics and therapy monitoring, stroke homecare and rehabilitation). Realization of asthma diagnostics by means of telemedicine devices makes possible to identify the disease without getting the patient travel to or stay in county centre for a longer period. According to the medical guide, inhalation and exhalation of the patient should be monitored for at least ten days, by this method patients can get over this process at their home, living their normal way of life instead of staying in hospital. Asthma therapy monitoring serves the patient’s personal therapy. Stroke rehabilitation realizes communication and co-operation among specialists, rehabilitation experts and patients allowing drastic cost reduction and increase of quality of life and sense of comfort of the patient.

The final objective is to have these processes accepted by healthcare representatives and to achieve that these processes are integrated into the national finance system that would make possible to widen service availability for those in need.

REFERENCES


Authors:

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Csaba Engel graduated from the Technical University of Budapest in 1995 as electrical engineer. He received his MBA degree from Buckighamshire New University (BUCKS) in 2008. He has been with Answare Ltd. since 1998. During his career he has obtained experience in integration of infocommunication infrastructure and systems, planning of integration activity, and carrying out projects in many areas: electronic message management, infrastructure management, IT safety, medical IT. Presently he is coordinating the tendering and competition activity of Answare Ltd.

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