Towards a Patient-Centered Collaborative Health Care System Model

Article *in* International Journal of Computer Theory and Engineering · January 2012

DOI: 10.7763/IJCTE.2012.V4.631

4 authors, including:

Elena Vlahu-Gjorgievska
University of Wollongong

Vladimir Trajkovik
Ss. Cyril and Methodius University in Skopje

Saso Koceski
Goce Delcev University of Štip

Towards a Patient-Centered Collaborative Health Care System Model

O. Kotevska, E. Vlahu-Gjorgievska, V. Trajkovic, and S. Koceski

***Abstract*—Recent advances in wireless sensor networks (WSN) technologies are enabling patient-centered, result oriented health care services, in the most cost-effective manner. Furthermore, technological advances are enabling a greater shift from institutional services to community-based services. The model of the collaborative health care system (COHESY) presented in this paper offers 24 hour monitoring of the condition of patients and the possibility of sending an emergency call for sudden deterioration of his medical condition. In addition, the system enables the patient (system user) to contact other people with similar condition and exchange their experience. This system improves the terms of home care treatment of the patient and also increases the medical capacity of the appropriate institutions. The result is significant reduction of the overall costs for patients and hospitals.**

***Index Terms*—Personal health care system, mobile application, social network.**

I. Introduction

Providing patients with convenient health facilities at a low cost has always been a great challenge for health service providers. Moreover, the fast changing life style of the modern world and the problem of aging society pose an urgent need to modernize such facilities. This involves devising cheaper and smarter ways of providing healthcare to disease sufferers. In addition, emphasis has to be paid on providing health monitoring in out-of-hospital conditions for elderly people and patients who require regular supervision, particularly in remote areas. Future trends in national healthcare services are expected to include shorter hospital stays and better community care.

Recent advances in WSN technology enable envisaging novel ubiquitous healthcare systems [1], [2] permitting mobile and permanent monitoring of patients, even during their normal daily activities, and without compromising their quality of life.

There is also a growing interest towards the adoption of mobile devices capability of accessing, analyzing and possibly updating patients' medical records from anywhere [3].

The recent trend in healthcare support systems is the development of patient-centric pervasive environments in addition to the hospital-centric ones [4]. Such systems enable healthcare personnel to be able to timely access, review, update and send patient information from wherever they are, whenever they want [5]. There are also, systems that are standards-based open (client and server) platform for interfacing to a wide variety of biomedical devices and sensors, collecting data from the devices and sensors, storing the data in a server repository, and making the data available to applications through a documented API [6].

Often, there are several building blocks and architectural models for Personal Health Systems [7], like: Network of biosensors, Personal gateway (Personal server), Clearinghouses, Medical Servers, and Medical Web Portal. But, the need for quality of service support in wireless e-health and e-emergency services is very important [8]. So, these systems have to provide quality of service support such guarantee for bandwidth, reliability, end-to-end delay, jitter and loss.

Pervasive health care takes steps to design, develop, and evaluate computer technologies that help citizens participate more closely in their own healthcare [9], on one hand, and on the other to provide flexibility in the life of patient who lead an active everyday life with work, family and friends [10]. However, these systems do not consider collaborative value that can be provided with matching gathered data.

The basic feature of mobile and Web services is exactly the communications that ease the collaboration. In the case of our proposed system, the communication paths between patients with the same diagnoses can be provided both directly, or as statistical summaries grouped by some indicator. This communication enables the exchange of patients' experiences in terms of therapy and rehabilitation, by using the experiences of the activities that have been taken by other patients.

The collaborative Information system model we present in this paper, gives a new dimension in the usage of novel technologies in the healthcare. This system use mobile, web and broadband technologies, so the citizens have ubiquity of support services where ever they may be, rather than becoming bound to their homes or health centers as pointed out by different authors [11]. Broadband mobile technology provides movements of electronic care environment easily between locations and internet-based storage of data allows moving location of support.

The most important benefits of our proposed system model are: increased medical prevention, more immediate time response at emergency calls for doctors, 24 hour monitoring of the patients' condition, possibility for patient notification in different scenarios, transitions of the collected bio signals

Manuscript received July 20, 2012; revised September 20, 2012.

O. Kotevska and V. Trajkovic are with the Faculty of Computer Science and Engineering, "Ss. Cyril and Methodius" University, Skopje, R. Macedonia (e-mail: trvlado@finki.ukim.mk).

E. V. Gjorgievska is with the Faculty of administration and management of information systems, "St. Kliment Ohridski" University, Bitola, R. Macedonia (e-mail: elena.vlahu@uklo.edu.mk).

S. Koceski is with the Faculty of Computer Sciences, "Goce Delcev" University, Stip, R. Macedonia (e-mail: saso.koceski@ugd.edu.mk).

(blood pressure, heart rate) automatically to medical personnel similar to the work of Komnakos, Vouyiokas, Maglogannis and Constantinou [12], increased flexibility in collecting medical data. Our system model creates the opportunity for increasing patient health care within their homes by 24 hour monitoring on the one hand, and increasing medical capacity of health care institutions on the other hand. This results in reducing the overall costs for patients and hospitals and improves the patient's quality of life [13].

II. System Overview

In a world with abundant, actionable health data – both from electronic medical records and our everyday observations – we will be empowered to make better decisions and our relationships with doctors may significantly change.

Therefore, in the process of designing a new healthcare system the following points should be considered:

1) Data on its own is not enough. It needs to be actionable.
2) Data needs to be accessible — to patients, policy makers and health care providers — to enable them to make better decisions.
3) "Every day" data needs to be considered and can be as valuable as lab tests in its impact on your health outcomes: how much you sleep, how much exercise you get, whether or not you are fighting with your spouse.
4) The focus needs to move away from the clinical setting to the individual's homes and the other settings where they live their lives. Doing so will require a number of changes, including the need to address how health care providers are able to bill for their services.
5) Patients and providers need to look at their relationship as a collaboration, which is going to require shedding old baggage about power dynamics in the doctor-patient relationship.
6) Technology offers new opportunities, but it is not the silver bullet. The technology cannot be intrusive; it needs to be a part of an individual's life.

Simple overview of our system model is presented in Fig.1. The system is deployed over three basic pillars:

1) The first one is consisting of the bionetwork (implemented from various body sensors) and mobile application that collects users' bio data during various physical activities (e.g. walking, running, and cycling).
2) The second is presented by the social network implemented as web portal which enables different collaboration within the end user community.
3) The third enables interoperability with the primary/secondary health care information systems which can be implemented in the clinical centers, and different policy maker institutions.

Communication between first and third component of the proposed model is determined with the communication between patient and health care centers. The patient has 24 hour access to medical personnel and possibility of sending an emergency call.

The medical personnel remotely monitors the patient's medical condition, reviewing the medical data (fatigue, blood pressure, heart rate) and respond to the patient by suggesting most suitable therapy (if different from the one that is encoded in the mobile application) as well as sending him/her various notifications (e.g. tips and suggestions) regarding his/her health condition.

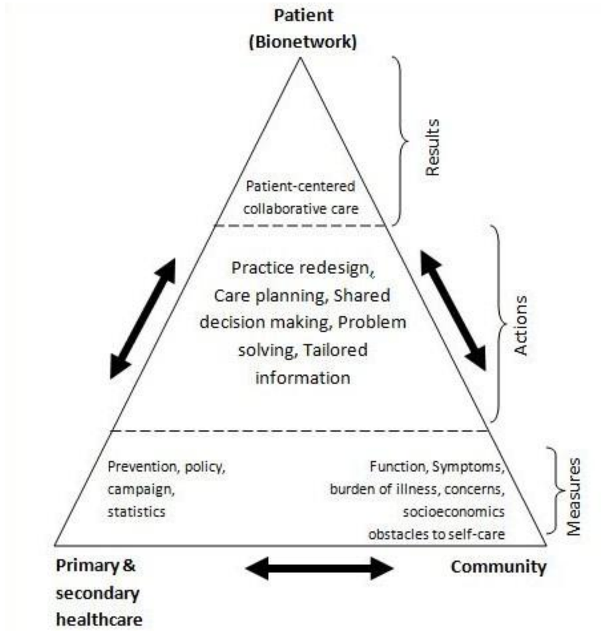

Fig. 1. Cohesy system layers.

Second and third component can exchange data and information regarding the larger group of patients group by any significant indicator (region, time period, sex, type of the activities) which can be later used for research, policy recommendations and medical campaign suggestions.

The proposed structure of the COHESY model strongly promotes the patients as a partner approach, often called Health 2.0 [10].

III. Validity of Information

One of the most important issues in the system is information validity and confirmation. We divide system information validity in three categories.

Most reliable information (valid information) is information in the first category. This information originates from the clinical centers, medical databases, and biosensors.

The second category (reliable information) is information generated from the Social networks. This information can be confirmed (transferred in the first category) if confirmed by the medical records from clinical centers. This confirmation is then deployed on data generated by corresponding algorithms implemented in the social networks.

Information from personal profiles (age, weight, height, diagnose entered by end user) are third category information (unreliable information). Increase of validation of this information can be done by comparing them with average results using social network or by confirming them with the medical records coming from healthcare institutions.

The categorization of information is used for determination of the validity of notifications and recommendations created within the system. This is important because it affects the users' decision whether to respect the notification/recommendation or not. The minimum category rule is deployed on all algorithms. This means that valid recommendations can be generated only if all data used to calculate recommendation is valid. The same stands for reliable recommendations (it is generated by valid and reliable date). All others recommendations and notifications are unreliable and should be treated as suggestions.

IV. Security Issues

The fundamental goals of secure healthcare systems are safely exchanging the patient's information issued by mobile devices, and preventing improper use of illegal devices, such as intercepting transferred data, eavesdropping communicating data, replaying out-of-date information, or revealing the patient's medical conditions. Based on the potential threats of mobile healthcare [10], specific security requirements will have a significant influence on the performance of the system:

A. Data Storage and Transmission

Local database (in mobile phone) stores data received by sensors, in case there is always back up of data (they will be saved only some period of time). When there are problems in sending data to clinical center, some of data is not going to be send, all transaction will be rolled back. In this way there will be always all sensors data and when service will be available data will be sending provide quality of service (QoS) facilities since these clearly demand for high reliability, guaranteed bandwidth and short delays.

B. Data Confidentiality

Most patients do not want anyone to know their medical information, except their family doctor or medical specialist. The solutions are to use a cryptographic algorithm to encrypt medical information and protect the necessary data.

C. Authentication

Only an authenticated entity can access the corresponding data that are available for that entity; unauthenticated entities are denied access when they visit data information that they do not have the rights to obtain. For example, asymmetric cryptography (i.e. PKI) is often used, because these private keys are credentials shared only by the communicating parties.

D. Access Control

In traditional network security models, access control determines whether a subject can access an object based on an access control list (ACL).

E. Privacy Concerns

Every user can choose what information can be private or public. User can choose his records to be public: (a) for medical purposes, (b) to all visitors of the Social network, (c) to users in his category, (d) to none. In order to have medical support the user has to agree to share personal information with clinical centers and medical databases, whose data are also protected. According to user agreement policy those data information would be exchanged through system.

Though many healthcare researchers are interested in collecting and recording medical sensor data, these data may contain many personal facts, meaning patients are not willing to reveal them [10]. Especially in an open wireless environment, an intruder may observe network traffic and thereby infer the relationships and identities of the communicating nodes.

One possible approach for solving this issue is to apply the theory of trust to identify malicious nodes and thereby exclude them from a presently healthcare network. As an emerging technique, trust can be defined as "the degree to which a node should be trustworthy, secure, or reliable during any interaction with the node" [14]. This means that if one node trusts another node to perform the intended operation, the trust relationship between these two nodes can be established reliably from the communicating initiator's point of view. So, the technique of trust evaluation without a centralized trust management authority can significantly improve the security and reliability of the network while also reducing the complexity of the traditional trust schemes and thus improving efficiency.

V. Detail System Design

The use of mobile technologies (devices and applications) in this system is not limited on communication. The mobile technologies are used to support and enable collaboration.

Collaboration between different entities of the Cohesy system is given on Fig. 2. The installed mobile application, using various sensors (bionetwork), performs readings regarding users health during his physical activities (walking, running, cycling) and based on them, gives appropriate instructions, proposals and constraints of their execution, in order to improve his own health. The application can also generate notifications and recommendation based on second system layer (collaborative filtering from data gathered in the social network layer) or third system layer (direct notifications from healthcare institutions).

The Cohesy system not only offers the possibility of sending an emergency call for sudden deterioration of patient medical condition. The patients are not restricted in their movements or their location. By using their mobile phone (the installed application) they have access to the medical personnel at any time. The medical personnel can remotely monitors the patient's medical condition, reviewing the medical data (fatigue, blood pressure, heart rate) arriving from the mobile application of the patient.

At the same time, the patient individual data can be compared with average data obtained using different collaborative filtering techniques.

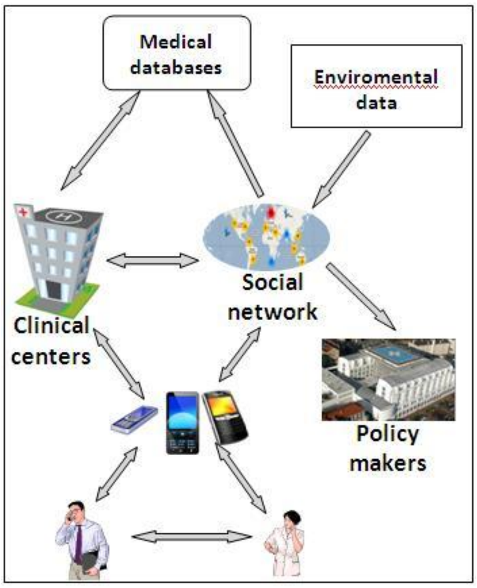

Fig. 2. Cohesy collaboration architecture.

In this way, medical personnel can quickly respond to the patient by suggesting most suitable therapy as well as when to receive it, focusing on activities that are necessary for his rehabilitation and maintenance of his health, sending him various tips and suggestions for improving his health. Even more important, the social network can learn from this recommendation and generate notifications and recommendation based on the most successful scenarios.

The installed mobile application has access to the social network (web portal) where it can store users' data and read average data readings on bio and physical activities of all users. Social network allows direct communication between users (if approved by the user and stored in the user profile) and sharing their results. This portal can provide interface and use data from a variety of medical databases and environmental databases (temperature, wind speed, humidity). In this way mobile application within the Cohesy system provides a tool for a complete personal healthcare.

The proposed Cohesy model is an infrastructure that enables various personal healthcare scenarios.

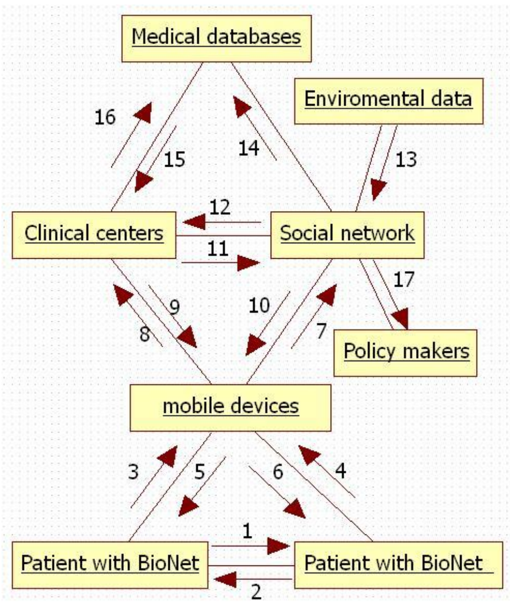

Fig. 3. Data flow diagram.

The conclusions drawn from research data, while exploring medical databases, can rout back to the clinical centers. These data are used to individually analyze the condition of patients. Clinical centers have access to data on physical activities of patients collected by the application installed on their mobile device. Therapies and recommendations are drawn from the analysis of the overall data obtained by clinical centers. Those therapies and recommendations now can be easily routed to the patients' mobile devices.

Simultaneously, clinical centers can exchange data and information with a social network and thus have access to a larger group of patients that can share research, recommendations and suggestions of the medical personnel.

Received therapies and recommendations can be used by the application to suggest to users when, where and what action to accomplish in order to improve their health.

The social network has incorporated collaborative filtering that allows filtering large amounts of data on concrete condition. So, policy makers can get those data, make specific analysis of it and gave recommendations for national action by governments and non-government organizations, including programs and strategies.

The data information in this system are: users' personal data (name, age, weight, diagnose), realized and recommended activity (type of activity, path length, time interval, average speed), recommendation and suggestions. The flow and exchange of these data in our system model is shown in the diagram on Fig.3. We must mention that data information send to Policy makers are filtered using different confidential conditions.

VI. Guideline for System Evaluation

The evaluation of the system can be made based on following parameters: number of patients, the average number of days of hospitalization and average occupancy of the hospital capacity.

Actually, there's a need for comparison between the number of patients (in a given period of time) before implementation of the system and number of patients (in the same period) within the implemented system. A second indicator is the comparison of the average number of days of hospitalization per patient (with certain diagnosis) before implementation of the system and average number of days of hospitalization after the implementation of the system. And third is the comparison of the involvement of hospital capacity before and after implementation of the system.

These three parameters are indicators of the effectively of the system and with them could be done qualitative analysis of the effectiveness of the system. This analysis will show the need and the impact of implementing such a system.

VII. Conclusion

In this paper collaborative patient-centered health care system model was presented. The system provides tool for personal health care by generating different recommendation, notification and suggestion to the users. The generated information has different validity depending on the validity of the data that is used to generate information. The model accuracy increases as the number of users increase. It also gets more reliable with time.

In addition to services for end users that our system model offers, the primary purpose of presented model is collecting different types of data and combining them into complex data structures based on collaboration. The survey, analysis and research of such structures allows to understand the impact and the influence of applied therapy, physical activity, time parameters and other factors on the development of the health condition of the patient. Such analysis can be further used by the clinical centers for diagnosis, treatment and therapy to patients. On the other hand, data obtained from clinical centers and social networks, through the application (handled by the application) allows the user to adapt and align his physical activities while improving his health condition and overall way of rehabilitation, meaning to be fully able to take self-care and professional concern about his health.

References

[1] T. Znati, "On the challenges and opportunities of pervasive and ubiquitous computing in health care," *Proceedings of the IEEE International Conference on Pervasive Computing and Communications*, Per Com, Kauai Island HI, USA, vol. 396, 2005.

[2] S.-V. L. Limited, S. I. Ahamed, M. M. Haque, and A. J. Khan, "Wellness assistant: A virtual wellness assistant using pervasive computing," *Proc. Symposium on Applied Computing*, USA: ACM, 2007.

[3] L. Chittaro, "Visualization of patient data at different temporal granularities on mobile devices," *Proc. Working Conference on Advanced Visual Interfaces*, USA: ACM, 2006, pp. 484-487.

[4] V. Koufi, F. Malamateniou, and G. Vassilacopoulos, "A medical diagnostic and treatment advice system for the provision of home care," *Proc. 1st International Conference on Pervasive Technologies Related to Assistive Environments*, USA: ACM, 2008.

[5] R. Chakravorty, "MobiCare: A programmable service architecture for mobile medical care," *Proc. 4th IEEE Conference on Pervasive Computing and Communications Workshops, IEEE Computer Society*, 2006.

[6] M. Blount, V. M. Batra, A. N. Capella, M. R. Ebling, W. F. Jerome, S. M. Martin, M. Nidd, M. R. Niemi, and S. P. Wright, "Remote health-care monitoring using personal care connect," *IBM Systems Journal*, vol. 46, no. 1, pp 95-113, 2007.

[7] M. Shopov, G. Spasov, and G. Petrova, "Architectural models for realization of web-based personal health systems," *Proc. International Conference on Computer Systems and Technologies and Workshop for PhD Students in Computing*, USA: ACM, 2009.

[8] O. Gama, P. Carvalho, J. A. Alfonso, and P. M. Mendes, "Quality of service support in wireless sensor networks for emergency healthcare services," *Proc. 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, IEEE*, 2008, pp. 1296-1299.

[9] S. I. Ahamed, M. M. Haque, and A.J. Khan, "Wellness assistant: A virtual wellness assistant using pervasive computing," *Proc. Symposium on Applied Computing*, USA: ACM, 2007.

[10] S. A. Ballegaard, T. R. Hansen, and M. Kyng, "Healthcare in everyday life: designing healthcare services for daily life," *Proc. Conference on Human Factors in Computing Systems*, USA: ACM, 2008, pp. 1807-1816.

[11] T. Carl and L. Dajani, "The future of homecare systems in the context of the ubiquitous web and its related mobile technologies," *Proc. 1st International Conference on Pervasive Technologies Related to Assistive Environments*, USA: ACM, 2008.

[12] D. Komnakos, D. Vouyiokas, I. Maglogannis, and P. Constantinou, "Feasibility study of a joint e-health mobile high-speed and wireless sensor system," *Proc. 1st International Conference on Pervasive Technologies Related to Assistive Environments*, USA: ACM, 2008.

[13] T. Zimmerman and K. Chang, "Simplifying home health monitoring by incorporating a cell phone in a weight scale," in *Proc. 1st international conference on Pervasive Technologies Related to Assistive Environments*, USA: ACM, 2008.

[14] A. Boukerche and Y. Ren, "A trust-based security system for ubiquitous and pervasive computing environments," *Computer Communications*, vol. 31, pp. 4343–4351, 2008

O. Kotevska received the BSc degree in information systems from the Institute of Informatics at the Faculty of Natural Sciences and Mathematics at the "Ss. Cyril and Methodius" University in Skopje. Currently she is an MSc student at the Faculty of Computer Science and Engineering, University in Skopje. Her current research interests include body wireless sensor networks.

E. Vlahu-Gjorgievska is a teaching and research assistant at the Faculty of administration and information systems management at the University "St.Kliment Ohridski" in Bitola. Currently, she is a PhD candidate at the Faculty of Computer Science and Engineering at the University "Ss Cyril and Methodius" in Skopje. Her research is in the field of collaborative information systems for health care.

V. Trajkovik received PhD degrees 2003. He joined the "Ss. Cyril and Methodius" University Skopje, R. Macedonia, in December 1997. His current position is the Associate Professor and the Vice Dean for Science at the Faculty of Computer Science and Engineering. He is currently responsible for several courses at undergraduate level, and "Mobile and Web Services", "Collaborative Systems" and "Innovative Technologies" at postgraduate level. He realized multiple research stays with several European Universities as visiting scientist within the scope of different EU and international projects. He is an author of more than 100 journal and conference papers. He has participated (as researcher or project leader) in 15 international projects sponsored by European Commission in the framework of TEMPUS, PHARE and FP programs.

S. Koceski received the PhD degree in robotics and artificial intelligence from the University of L'Aquila (Italy), in 2009. He is currently an Assistant Professor at the Faculty of Computer Science, University "Goce Delcev"- Stip, R. Macedonia. His current research interests include robotics and artificial intelligence, bioengineering, bioinformatics and medical imaging.