Medical and Home automation Sensor Networks for Senior Citizens Telehomecare

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***Abstract*- This paper presents a home Tele-healthcare system for the senior citizens. The system uses home automation sensors to detect activity level of the persons. It is equipped also with other technologies to monitor them and detect any abnormal state in their health situation, like as bed and chair sensors, a mini PC connected to a TV, medical sensors, a wireless camera network. The system detects health abnormalities at an early stage through the frequent monitoring of physiological data. The system is designed for the elderly patients who wish to spend their old age in their own home, because of its potentials to increase independence and quality of life for seniors who prefer to live in their own homes and to realize cost savings for the health care system. By using this system MEDeTIC, a non-profit organization proposes a new concept of building smart homes named "Vill'Âge" at France.**

Keywords: Telemedicine, Tele-Healthcare, Elderly Healthcare, Smart Home, Distributed health record, Actimetry, Fuzzy logic, Home automation

I. INTRODUCTION

Nowadays a big rate of dependent elderly requiring healthcare services must leave their home and move to special healthcare centers and this is often not acceptable for them. Advanced communication networks and Internet technologies have a key role in the development of smart homes. Healthcare integrated smart homes can be used to allow the seniors and their family members to benefit from a safe home environment with activities and services accompaniment for their daily steps. These technologies have a key role in the development of smart homes.

To reach these benefits, most countries are now facing an urgent requirement to provide appropriate retired home environments solutions for senior citizens and allow them to rest in their own homes. For same reasons, elderly tele-homecare, videoconferencing and tele-consultation systems have been attempted by many researchers too.

Many telemedicine and e-health systems are being developed and many innovations and ICT-based emerging solutions are close to be operational, nevertheless the expected take-up did not occur yet, since proposed systems and their targeted medical benefits are certainly too segmented and disconnected the ones from the others. In addition, most of existing products and services in this field rely on proprietary technologies, which is a substantial obstacle to the development of complementary services or applications, and thus of the market.

Consequently, population like elderly, disabled people or chronically ill people, who are often suffering from co-existing troubles, are not encouraged to dare benefiting from ICT and innovations, as available solutions are not complete, not compatible the ones with the others, not scalable, neither end-to-end nor comprehensive, and remain then unaffordable for someone who would try to subscribe to each relevant service covering a more or less significant part of its medical and social needs, without ensuring a global management of the daily problems.

The fragmentation of experimentation, projects and products did not yet give birth to any efficient and affordable holistic solution that could fulfill the various targeted beneficiaries and users' expectations. The development costs and R&D expenses required for a proper adaptation to each community of users and beneficiaries' needs make investment very high, as time-to-market delays are uncertain and no business model has been successfully assessed yet in this domain. The accompanying measures, at institutional, ethical, legal, financial and organizational levels remain insufficient, which prevent the development and the sustainability of such assistance and at-home monitoring services.

Finally, the population is neither confident nor familiar enough with these innovation-based solutions, especially in such a medical or health-related purpose, although their development requires that they become a natural component of the medical and social environment and infrastructure. For instant, in this section we will name just some of the existence systems.

The remainder of this paper is structured as follows: section II discusses state of the art. Our system, its uses and functionalities are described in section III, while section IV describes challenges and some discussion notes. Our studies and future works are resented in section V and section VI provides concluding remarks.

II. STATE OF THE ART

A telehealth application is a complex system that requires the integration of various sub-systems and applications. As we said, nowadays, many telehealth and e-Home applications are available; however, it is difficult to find the system that matches exactly the end-user requirements. The current developments and innovations are limited in terms of commercial and operational perspectives and suffer from certain essential phenomena.

In [2] the authors presented a teleconsultation system. This system is based on web technologies and the user accesses the system over the Internet or an intranet. The system therefore is designed to do a teleconsultation, and it is not integrated with the other healthcare modules or an automatic analysis of patient's health situation.

TOPCARE [3] is a telehealth system for mobile care and homecare of high risk patients, elderly and care needing people. The system is an open telecare platform solutions for telemedicine services. The overall objective of TOPCARE is to develop technical devices and telecommunication structures and to lay the organizational groundwork for bringing co-operative health care services into the home of patients. System comprises a telematic homecare platform (THP) backbone, the development of telematic home stations (THS) and health professional stations (HPS) and a communication server that will manage the network administration, the health professional registration at the THS, the device communication, and the Internet access. Therefore, in TOPCARE, interaction is limited to only the clients having TeleHealth Client (THC) module.

The Interactive and cooperative tele-monitoring of the dialyzing at home (DIATELIC) is a system of tele-monitoring of dialyzing at home by the technology of DPCA (Dialyze Peritoneal Continue Ambulant) [4]. It was developed by LORIA in cooperation with the doctors of the ALTIR (Lorraine Association of Treatment of Renal Insufficiency) and a doctor advice of the Health insurance. Research works drove to the Diatelic system. This system is only designed especially for the dialyze patients.

The AFIRM team of the laboratory TIMC-IMAG in Grenoble developed a project called System of Information and Communication of the Inteligent Home for Health (SIC - HITCH) [5]. Objective is to monitoring the patient in his home with sensors installed in his home, by triggering off alarms in the appropriate urgent centers, in case of feelings of faintness, in falls or in abnormal situations. This system is an experimentation and simulation platform.

III. PROPOSED SYSTEM

The requirements presented in the previous sections and remaining obstacles or brakes make the design of monitoring and assistance tools quite complex, as each pathology or disability generates its own set of requirements and constraints. Such context increases the need for the development of innovative global ICT-based solution allowing to implement personalized and person-centric care process and tools, which can evolve with the users' medical and social and physical evolution, and which can compile the various collection and analysis of data to ensure a reliable and sound diagnosis, medication and evaluation of the medical and social state of the person. To reach these advantages, we developed a patient oriented system.

A. System architecture

By a user requirement analysis, we propose a Multi-tiered architecture. Fig. 1 shows the system's general architecture. The elements of this architecture are:

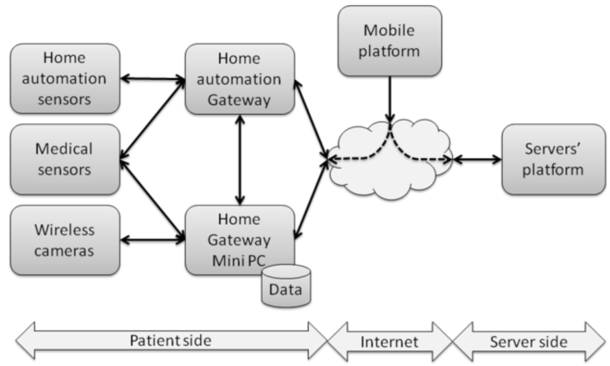

Fig. 1. System's general architecture

- Medical Sensors network (and/or Body Sensor Network (BSN)): This part consists of the medical instrumentation important to patients medical monitoring. This network consists of very small portable devices equipped with a variety of sensors for biological monitoring, patient localization and identification.
- Environmental Sensors and Home automation sensors network: This network must include sensors unfolded in environment (rooms, halls, WC …). These sensors can include those of the temperature, humidity, movement, acoustics, bed and chair sensors, etc.
- Wireless cameras network: this network is used to fall detection and validation. (See V)
- Home automation gateway: to communication with home automation sensors. The information of the sensors in this gateway is used also to activity monitoring in the Home Gateway.
- Home Gateway: It is a mini PC installed in each home. It connects body sensor network and also environmental sensors like home automation sensors and actuators to the Internet. It also includes intermediate receivers, assuring an efficient data transmission. In this gateway we do some preprocessing of the data received from medical and home automation sensors, to detect urgency anomalies.
- Mobile platform: this is a PDA or a laptop computer to receive the alerts and message by a professional, or to connect to server platform and view the patient's record. This platform can be used by persons to remote control his/here home.
- Server platform: consists of the different servers like: medical record, application, videoconference and web servers.

Fig. 2 shows the hardware architecture. It presents the different hardware that must be installed in each home; it also shows the different platforms of the system.

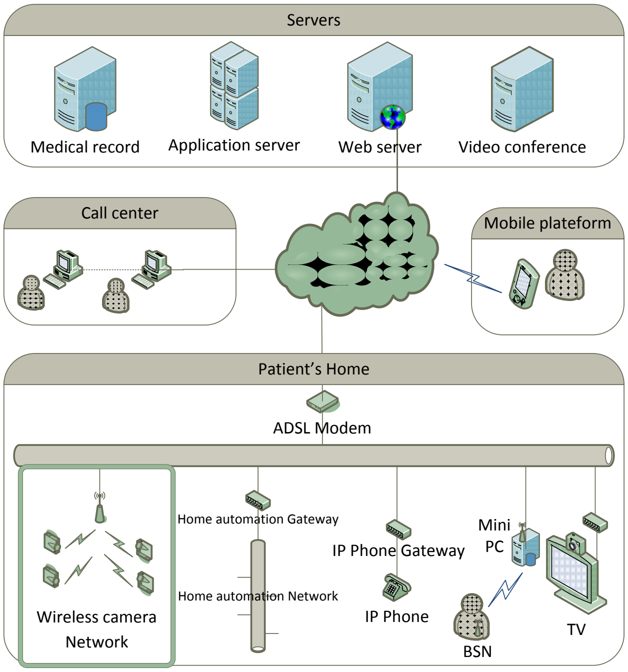

Fig. 2. Hardware architecture

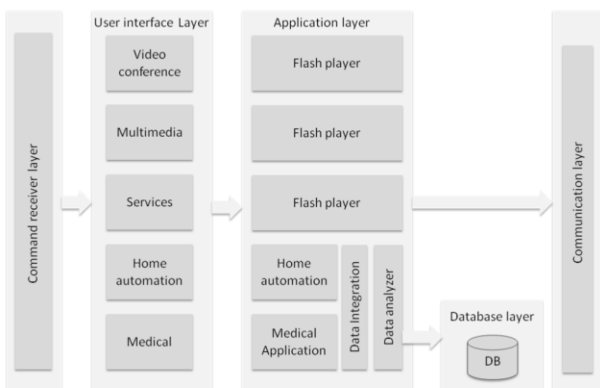

Fig. 3. Software architecture

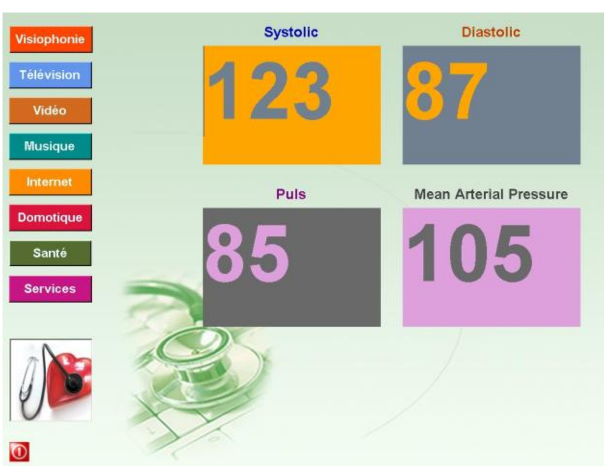

Fig. 4. Medical Interface

B. *Software architecture*

Fig. 3 shows the software architecture of the system. As we can see, we used a modular multilayer architecture in this system. The architecture has 4 layers:

a) *Command receiver layer:*

This layer receives the commands from remote controller and transfers them to user interface layer. This system can work with different types of commands, as like as sound, a normal IR remote controller and also PDA. We developed a remote controller application for PDA that uses Wife to communicate with PC. This layer receives also the data from different medical and home automation sensors.

b) *User interface layer:*

This layer presents a simplified user friendly and dynamic graphical user interface. This layer is a modular and has 5 different modules: Video conferencing, Home automation, medical, services and multimedia (TV, Video and Music). Fig. 4 shows the medical interface of the application.

c) *Application layer:*

This layer has also 5 main modules: Video conferencing that consists of Flash player, media player for multimedia, service, Home automation, Medical, data analyzer, data integration and local database. The data received from Home automation and medical sensors will be integrated in Data integration and then Data analyzer will analyze them to detect and anomalies.

d) *Data base layer:*

In each mini PC we have a local data base which save all the information received from different sensors. This data base is synchronized with the main data base in the web server. The pre-process in the mini PC will be search to detect most urgent problems in health state of the person. And in the central server application will process the data to do activity monitoring and to detect problems like diabetes risks and...

e) *Communication layer:*

This layer facilitates the communication between PC and servers via Internet and also between PC and Home automation devices.

C. *Distributed patient record and web services technology:*

As shown in Fig. 3, the patient record has a distributed architecture, and we have a local database in each client computer. We used a distributed patient record because in distributed database architecture the data is not stored entirely at a single physical location. Instead, it is spread across a network of computers that are geographically dispersed and connected via communications links. We have therefore a large database capacity and incremental growth, and like all distributed databases, we have a reliable, available and flexible database. The most important advantage of a distributed database for our system is that a distributed database allows faster local queries and can reduce network traffic. In this system, in each client computer we have a pre-treatment of patient's data to detect the eventual emergency problems.

This distributed database architecture helps to early detection of emergency problems, that means by checking the local database, if the data from healthcare devices are outside the ranges defined in their care plan, or if the data have not been received when expected, the system will trigger an alarm that may result in an automated connection with a medical call centre.

This system uses web services to interact between the client and the server and it has intention to address the need to standardize the transmission of physiological data, by using the platform independence of web services and the structural independence of XML in the development of a web service for data transmission, processing and storage of physiological data for the service of tele-monitoring. By using web services, the system requires minimal additional technological elements and minimal technical requirements of support.

D. Home automation system and Activity monitoring

The system gives not only to the patients a full control of Home automation devices, by using system's simplified interface but also generates the alerts by using home automation sensors, which allow an indoor localization of the beneficiary and can, thus, propose a fall detection service generating alerts. For instance, the system allows doctors or healthcare providers to measure the physical activities of elderly. The system uses a more passive method. It senses a person's presence in a room by home automation sensors installed throughout the living areas, such as motion and presence detectors, light, magnetic and temperature sensors.

Activity patterns are then analyzed in the central computer for unusual behavior, which use an intelligent method by using Fuzzy Logic. On the other hand, by using the data from home automation sensor and medical devices, the application stored in the web server, will analyze the medical record by using intelligent methods like fuzzy logic or other more complex cognitive systems, to find the potential health problem. By detecting a problem, the system will trigger an alarm that may result in an automated data transmission to a Doctor.

E. Video conferencing and Tele-consulting

Telecare is related to offer health care services over Internet or a wide area network, and in this domain, videoconferencing is one of the important solutions, allowing real-time interaction between patients and the Doctors. The offered system is integrated with a simplified and user-friendly videoconference system which is adapted to elderly needs. This sub system is used to have a video meeting by the families and also to request an online consulting. The teleconsulting steps are:

1. Patient connects to videoconferencing system
2. System sends a message to Doctor
3. System loads patient's medical record to Doctors computer
4. Doctor joins the conference
5. Consulting
6. Doctor fills the consulting form and saves it to medical record
7. End of consulting
8. System generates a billing and sends it to patient
9. Patient can view the billing in his interface and can pay it online

IV. CHALLENGES

In this type of systems, several challenges need to be addressed. The technological challenges regard the generic features of the dynamic database, of the wireless sensor networks, of the different supporting platforms, of the video call centre, and web services, to allow a flexible and smooth interaction among those items and to anticipate further additional functionalities, interacting devices, and so on. In this respect, the methodology of specifications, development and integration of the technological features must be realized with a major concern for some important concepts, like: Interoperability, Scalability, Evolution and customization according to the users' medical and social profiles and needs.

In addition, as the healthcare industry is turning to information technology to help solve its business issues, specially provide to quality patient care services, it is important to develop QoS (Quality of Service) specification in distributed health information systems [7].

Unlike traditional systems, many non-end-to-end mission-critical applications envisioned for healthcare systems, which are complex systems, because in these systems, we can find different subsystems, such as, wireless sensor networks, LANs, software platforms, home automation systems, mobile systems, Internet… that require different QoS requirements on the system, and these requirements pose unprecedented challenges in the area of QoS support in healthcare systems. Any failure or lack of performance on the system which could not be tackled in a reasonable delay may have some damageable consequences on the solutions' acceptance and development potential: the confidence is a basic and elementary factor of acceptance or reject, such incident could also generate a psychological defiance towards ICT's in general and towards such innovative assistance and monitoring services.

V. EVALUATION

For the technical evaluation of the system, a flat is entirely equipped to act as demonstrator and as laboratory. We did some studies also to evaluate the system between the senior citizens, as like as [1]. Our first study shows that all the healthcare professionals have a positive attitude toward dedicated means for ICT practical application (50% "totally agree", 33.3% "strongly agree" and 16.6% "lightly agree"). Majority of interviewed elderly residents, in this study, declare not knowing what would be their family attitude toward ICT use (45.83%); 37.5% think that their family would be favorable to ICT use and 16.67% think that the family would be unfavorable to ICT use, but this study with the projected family attitudes of elderly people shows that the limitations experienced in everyday life do not lead to a favorable or unfavorable category of ICT user [1].

Due to these results, definition and revision of planned applications (scenarios improvement), behavioral intention and acceptance of designed implemented solutions and finally actual usage and acceptance evaluation are important parameters in system development and design.

For this reasons design and integration effort for the technical and R&D activities of our project focus on the design of services and interfaces ensuring a maximum level of natural understanding on the way to use them, that is to say with an enhanced effort on the prerequisite and experimentation feedback's of the users who are suffering from chronic conditions and are not familiar- and sometimes reluctant- with ICT and innovation-based devices and systems. Ergonomic interface, accessibility, scalability and evolutionary solution according to the evolution of the users' needs are the important aspect of development.

VI. CURRENT WORKS

This section will present come of our current works and projects to complete the system. The first part will present our project to integrate ZigBee environmental sensors with home automation sensors. This is a common project with Schneider Electrics Company – France section. (See: http://www.schneider-electric.fr/). Second project presented in this section, is a Fall Detection project by many French companies.

A. Integration ZigBee with Home automation protocols

As we said in III.A and the Fig. 3 shows, the system is integrated with vital sign monitoring devices and sensors. The system has possibility of integrating the system with the wireless devices and sensors with different communication methods such as Bluetooth, ZigBee, USB and the other technologies. The medical data are store in the database aromatically; without any manual action. We aim in this project to integrate ZigBee protocol with home automation protocols, such as KNX, IHC. Among the many wireless technologies, ZigBee is one of the most promising ones for home automation; a wireless home networking system can be configured using ZigBee alone [6].

B. Fall detection with wireless camera networks

Nowadays, the best choice for elderly fall detection is to use a bracelet with a push button around the neck. Unfortunately, if the person forgets to carry the system, it is possible that the help does not arrive early. The idea of this project is to resolve this problem by using a noninvasive and automatic system to accomplish a system of surveillance at home for the seniors living alone. By using a camera installed in every room and home automation sensors, we will be able to follow the person and detect potentially dangerous situations.

In addition, by detecting such event, it will be possible to alert a medical call centre, and if needed, to urgent services. The cameras installed in the home send the images to a mini PC which is equipped with an application will use group of home automation sensors and cameras and an intelligent algorithm to detect a fall.

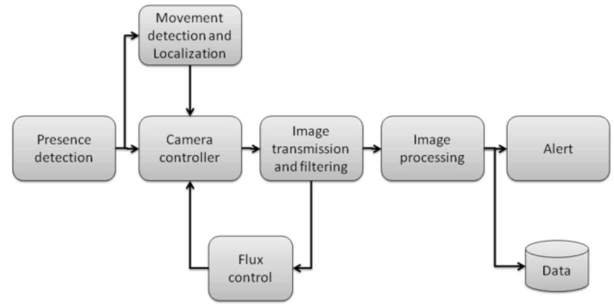

Fig. 5. Functionnal architecture of fall detection system

Fig. 5 shows the fonctionnal architecture of this fall detection system. As transmission is made via wireless or wired network which is also shared by other applications like home automations, we use a feedbacking system (Flux control) in order to manage the load of the network. In case of a big load in the network, images will be transmitted with a bigger delay and thus the transmission rate will change dynamically. In image transmission, we also use a filtering algorithm (m,k)-filter [8] proposed in TRIO team of Loria. The application analyzes the images to detect if the person is in a critical situation or not using the information of home automation sensors, the system already knows the exact position of person and can therefore determine if a help is necessary.

VII. CONCLUSION

In this paper, we have presented a distributed system to support remote medical consultations and elderly management and homecare across global wide area networks and heterogeneous platforms. By using this system, MEDeTIC (www.medetic.com) , a non-profit organization, offers a new concept of building smart homes by using telemedicine and home automation, named in French "Maisons Vill'Âge®". The first housing schemes are in building with implements of the system's components.

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