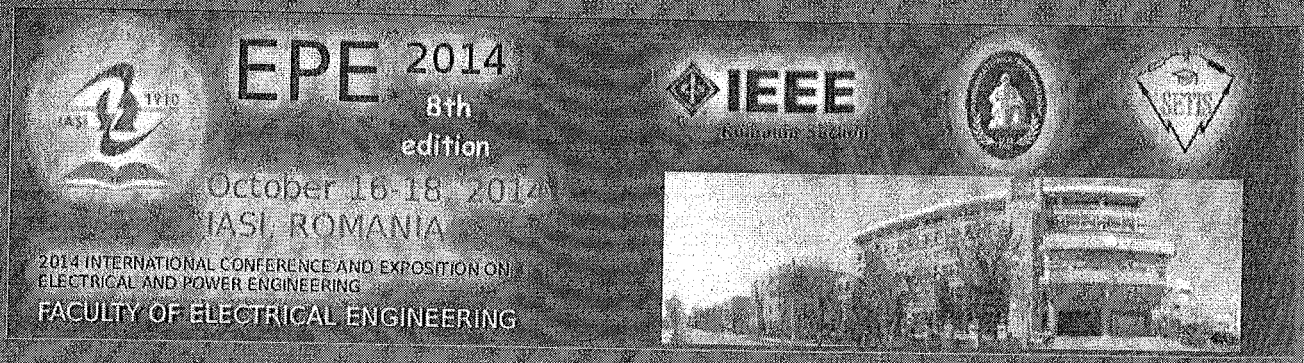

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of the

2014 INTERNATIONAL CONFERENCE AND EXPOSITION ON ELECTRICAL AND POWER ENGINEERING

Organized by

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Adopting the Internet of Things Technologies in Health Care Systems

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***Abstract*—Internet of Things based health care systems play a significant role in Information and Communication Technologies and has contribution in development of medical information systems. The developing of IoT-based health care systems must ensure and increase the safety of patients, the quality of life and other health care activities. The tracking, tracing and monitoring of patients and health care actors activities are challenging research directions. In this paper we propose a general architecture of a health care system for monitoring of patients at risk in smart Intensive Care Units. The system advices and alerts in real time the doctors/medical assistants about the changing of vital parameters or the movement of the patients and also about important changes in environmental parameters, in order to take preventive measures.**

Keywords*— *health care system; smart environment; internet of things; Kinect; sensors.

I. INTRODUCTION

Internet of Things (IoT) is "a new revolution of the Internet" [1], thanks to the ability to connect remote and mobile things or machines or assets through the use of wireless communications and low-cost sensors, computing and storage devices. So, the Internet is now advancing from a network of computers to a network of things.

Currently there are many definitions of IoT, which may vary depending on the context, the effects and the views of the person giving the definition. The definition of IoT can be "a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual *things* have identities, physical attributes, and virtual personalities" [2]. The Internet of Things offers solutions based on the integration of Information Technology (IT), which refers to hardware and software used to store and process data, and Communications Technology, which includes electronic systems used for communication between individuals [1].

The goal of the IoT is to enable a variety of things/objects present in the environment to be connected in order to interact and cooperate "anytime, anyplace, with anything and anyone, ideally using any path or network and any service" [1]. It is estimated that the number of Internet-connected devices exceeds the number of human beings on the planet in 2011. According to Cisco company there will be at least 25 billion Internet-connected devices by 2015 and doubly to 50 billion by 2020. For every Internet-connected personal computer there will be 5 to 10 other types of devices Internet-connected such as smart phones, gaming consoles, Wi-Fi routers, iPods, smart TV sets, connected stereo systems and other media devices. In the IoT network the things or objects are identifiable and can communicate information about them [1].

The research and development of technologies such as micro- and nano-electronics, communications, sensors, Radio-frequency identification (RFID), smart phones, embedded systems, cloud computing and software challenges contribute to the creation of a world where the real, digital and virtual are converging to develop smart environments that produces innovations in many different sectors. Potential applications of IoT are many and diverse, and the main domains are [1]:

- **industry** which involves financial/commercial transactions between companies [2], such as smart grid, water flow, liquid presence, tank level, photovoltaic installations, etc.;
- **environment** which includes activities regarding the protection, monitoring and development of natural resources [2], such as forest fire detection, air pollution, landslide and avalanche prevention, earthquake early detection, air quality, water quality, water leakages, river floods, etc.;
- **society** which includes initiatives regarding the development and inclusion of societies, cities and people, such as health care systems, smart parking, traffic congestion, smart lightning, waste management, intelligent transportation systems, etc.

Developing the technology in Europe will be much nearer to implementing smart environments by 2020. In the future computation, storage and communication services will be distributed. People, smart devices, machines, platforms, equipped with wireless sensors or RFID tags, will create a general pool of resources interconnected by a dynamic network of networks [1]. In the following ten years, trillions of sensors will be delivered. These sensors will be used to measure almost everything, from energy use, health conditions, air pollution to acceleration and location etc. [2]. Application of IoT technologies in green related and health care applications is one of the most encouraging market segments [3].

As it is a technological basis of IoT, research and development is also needed in the area of reconfigurable hardware, such as Field-Programmable Gate Array (FPGA),

where the configuration can be changed dynamically in order to introduce useful changes to the required description [4].

II. Health Care and Internet of Things

Advances in information, telecommunication, and network technologies play a significant role in health care systems and have contribution in development of medical information systems. However, health care represents one of the important social and economic challenges that every country faces, and health care administrators, clinicians, researchers, and other health practitioners are facing increasing pressure to adjust to growing expectations from both the public and the private sector.

A major impact on the quality of people's life is the rising cost of medical care and these costs are even higher in the case of chronic diseases [5]. The number of elderly is increasing continuously, which puts pressure on social and health services [6].

The development of health care systems demands a concerted effort to harness the power of information and communications technologies in the service of health care in order to create more efficient, effective, and secure data sharing, large-scale health information processing, and more effective communications [7].

A number of connected devices have been developed to improve health care delivery using sensors to collect information and cloud hosted analytics software that analyses data. Over the past 10-15 years, health care providers have increasingly become connected through the use of mobile computers, tablets, PCs, smartphones, Wi-Fi phones, and communications badges [8] and help them to become far more proactive about Health Services Delivery.

The illustration from Sierra Wireless [9], showed in Fig. 1, describes how a health care provider could theoretically use real time data collected from hospitals, wearable devices, home health monitoring devices, and elsewhere to provide better services [8].

Many patients who require constant health monitoring prefer the comfort of home monitoring to hospital environment. In case of remote monitoring patients can use a variety of monitoring devices such as glucose meters, pulse

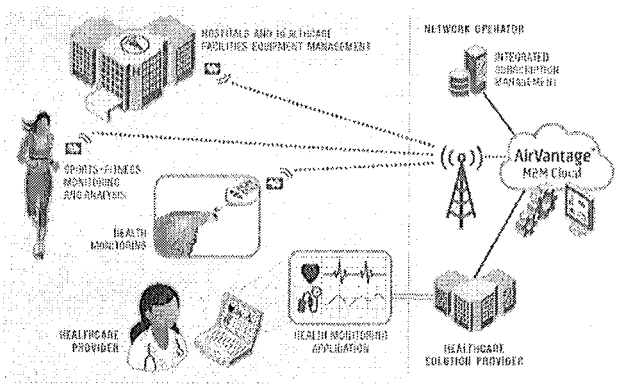

Figure 1 Real time monitoring of patient health through IoT [9]

oxymeters, weight scales etc. The main difficulty in home monitoring is making patients to provide accurate data to health care specialists. A number of companies are developing further connectivity solutions to improve not only communications between health care givers and patients, but real time monitoring of patient health as well [8], [10].

The problems of the Romanian Health System are similar to those of other European countries. In present, Romanian medical sector has not fully embraced the advantages and benefits of recent technologies that are used in health care sector. For instance, the medical staff has to deal with amounts of patient's medical records. The health care services costs are expected to grow due to the aging of the population and the increasing demand on health systems [6].

The new health care systems support the doctors and elderly people or patients with chronic diseases in managing the health care process in order to achieve an optimal health status or to avoid a worsening of the illness as long as possible. Recent evolution in health care domain has consistently shown that combined technologies have the possibility to resolve particular problems of the health domain.

III. Health Care System for Monitoring of Patients at Risk in Smart Intensive Care Units

Technological advances in the communication field and embedded systems allow the design and development of mobile communication systems with low power consumption and high computing. These characteristics are essential for the development of mobile health monitoring systems. At the same time, the aging of the population and the prevalence of chronic disease have increased the need for at-home health care, but employing medical personnel will lead to an increase of medical costs. A solution is remote monitoring or tele-monitoring that helps the physicians to follow up the progress of the patient and decide if a medical assistant or a doctor must be present or if the patient will be transported to another medical facility. In this way patients retain the quality of medical services but at lower cost.

In this paper is proposed the architecture of a health care system for monitoring of patients at risk in smart Intensive Care Units, using the concept of Internet of Things. The Intensive Care Unit (ICU) is hospital sector where patients require close observation and need constant attention or special drugs because they may have suffered serious injuries or they may have recently suffered major surgery.

The monitoring in the Intensive Care Unit is made through ICU monitors and all patients are connected to a bedside monitor. This monitoring of patients includes diagnosis, monitoring of vital parameters, prevention and treatment of all the vital functions. The patients have different types of sensors or sensing devices attached to their body which are connected to the ICU monitor by wires. The sensing devices send electronic signals through wires to the ICU monitor. This monitor displays specific signals and can generate alarms, which can signal to the medical staff if a body function needs attention. However, some patient's movements can cause the removal of the sensing devices wires. The general architecture

of health care system for monitoring of patients at risk in smart Intensive Care Units is presented in Fig. 2.

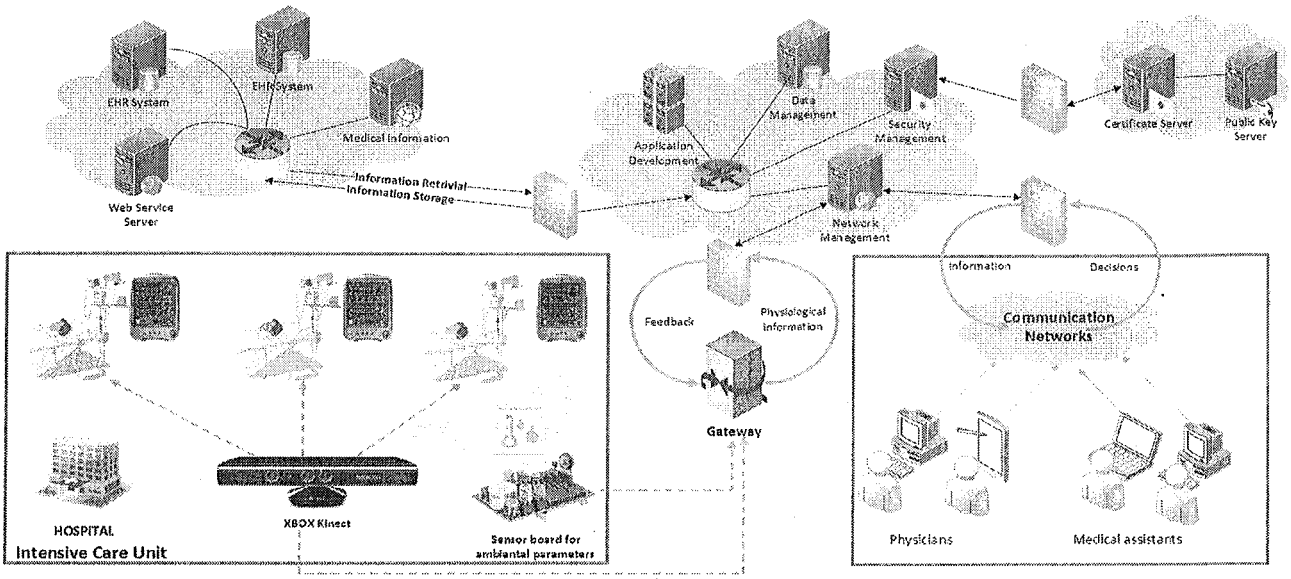

Figure 2 Architecture of the health care system for monitoring of patients at risk in smart Intensive Care Units

In order to create a smart environment for Intensive Care Unit (ICU) monitoring of patients at risk we will use the following components:

- Intensive Care Unit bedside monitors that are already used in hospital units to monitor and record multiple physiological parameters of patients;
- Microsoft XBOX Kinect™ using sensors to monitor the movement of the patients in order to eliminate situations in which the patient has removed from the sensing devices wires or the monitor generated a false alarm; this movement device will act only in cases in which the sensor device itself has not the facility to measure the contact resistance with patient;
- Sensor board for monitoring of environmental parameters such as temperature, humidity, atmospheric pressure and different types of gases.

A. Intensive Care Unit bedside monitor

The Intensive Care Unit monitor is used for monitoring and recording of, and to generate alarms for, multiple physiological parameters of patients in a hospital environment. The most commonly monitored functions are: breathing rate and oxygen saturation, heart rate and rhythm, blood pressure, body temperature [11]. The monitor can store or print the patient reports and is capable of functioning with a wireless infrastructure.

B. Kinect sensors

In order to monitor the movement of the patients at risk from ICU and create a smart environment we will use the sensors from Microsoft XBOX Kinect™. This device has a set of sensors that is able to detect movements, identify faces and recognize speech, through sensors that can acquire image, audio and depth information. The Kinect™ does not require the patient to wear any kind of sensors or devices. We will use the NUI (Natural User Interface) Skeleton Tracking module that provides a specific class for the management of the properties of the detected skeleton.

Kinect can detect at most six skeletons simultaneously, and the number of detected people is limited only by how many they will fit in the field-of-view of the camera. When a patient is detected, he/she is modelled with the class "Skeleton" [12]. Class Skeleton has several information fields related to joints, position, tracking, etc. An interesting aspect are the 20 joint points that identify specific parts of the body as the head, hands, feet, shoulders, knees, etc., as showed in Fig. 3. For each joint there are information related to the tracking and the position, in space coordinates x, y and z, and each joint is marked as "tracked" or "inferred" [12].

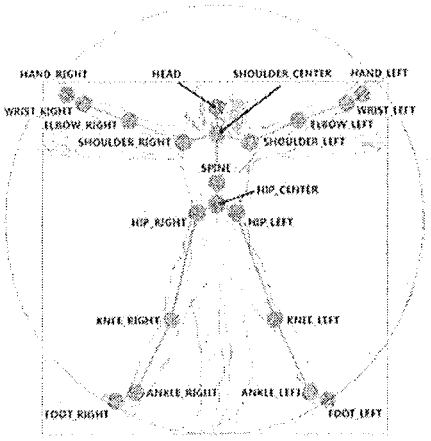

Figure 3 Skeleton of a user and all the tracked points [12]

C. Sensor board for monitoring of environmental parameters

In order to monitor the environmental parameters from Intensive Care Unit inside hospitals we will use a board that

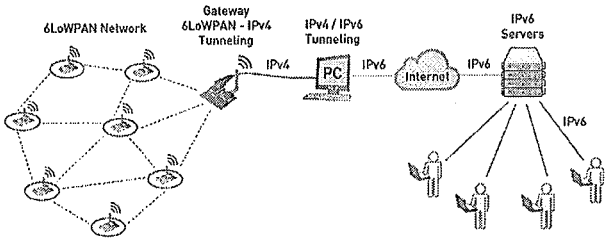

Figure 4 Sensors network for monitoring the environmental parameters [13]

has sensors integrated to gather the information about the indoor parameters and send it to a Gateway device. The sensors board has been designed to monitor temperature, humidity, atmospheric pressure and different types of gases (Carbon monoxide, Carbon dioxide, Nitrogen dioxide, Methane, Ammonia, Alcohol derivate, etc.). As well, movement and vibrations can be measured by the internal accelerometer. The device receives sensor data and forwards them to the Internet via Ethernet, Wi-Fi or GPRS protocols depending on the connectivity options available in that area [13]. In case connectivity fails, data can be stored in an internal data base. The gateway sends the information to the Tunneling machine that will send the information to Servers located on the Internet, where users are connected (Fig. 4) [13].

All health records and measurements were stored into a computer server and a data base that can be accessed by the doctors/nurses through a user friendly interface. The web-based health monitoring application will analyze and process the data information from all the devices from ICU and informs in (almost) real time the doctors/nurses about the changing of vital parameter or the movement of the patients and also about the important changing in environmental parameters, in order to take preventive measures.

D. Telemonitoring of vital signs

Another useful application of IoT concept is the remote monitoring of human's vital signs, such as blood pressure, electrocardiographic signal, oxygen saturation, body temperature and heart rate. This can be done by means of embedded medical sensors and wireless technology [14], [15].

IV. Conclusions

Internet of Things applications are pushing the development of platforms for implementing ambient assisted living systems that will offer services in the areas of assistance in daily activities, health monitoring, enhancing rapid access to medical and emergency systems. In present, the patients monitoring in hospital environment are made by medical personnel/assistants/nurses in which case the human error is inevitable.

In this paper we propose the architecture of a health care system for monitoring of patients at risk in smart Intensive Care Units (ICU) through the Internet of Things paradigm, using the recent methods and devices such as XBOX Kinect™ and a set of sensors for monitoring of environmental parameters. The main objective of our system is to enhance medical condition for people who need permanent support or monitoring, to decrease barriers for monitoring important health parameters, to avoid unnecessary health care costs and efforts, and to provide the right medical support at the right time. The authors have achieved system architecture acquiring the hardware parts and configuring the software for XBOX Kinect™. The system is in the process of testing and validation. The system is part of a more complex system in development and will be improved by adding new types of sensors (pressure, body weight, etc.).

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