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Internet of Things as Key Enabler for Sustainable Healthcare Delivery

Cristina Elena Turcu[a,]*, Cornel Octavian Turcu[a]

[a]*Stefan cel Mare University of Suceava, Faculty of Electrical Engineering and Computer Science, 13, University Street, Suceava-720229, Romania*

Abstract

Many errors occurring in healthcare are related to the lack of availability of important patient-related medical information. According to researchers, the use of information and communication technologies (ICTs) hold promise for increasing the accessibility of medical information and it is essential for patient safety. Furthermore, new developments in information and computing technologies will lead to subsequent dramatic changes in the healthcare environment. A vast and multilayered infrastructure of ubiquitous computing technologies and applications is emerging. The current widespread deployment of cell phones, laptops, Wi-Fi, Bluetooth, personal digital assistants (PDAs), and various forms of sensing devices based on digital and radio frequency identification (RFID) technologies penetrate the healthcare environment. The Internet of Things infrastructure allows connections between different entities, such as human beings (patients, medical staff, etc.), medical devices, intelligent wheelchairs, wireless sensors, mobile robots, etc.
This paper aims to show how radio frequency identification, multi-agent and Internet of Things technologies can be used to improve people's access to quality and affordable healthcare services, to reduce medical errors, to improve patient safety, and to optimize the healthcare processes.

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Keywords: healthcare; Internet of Things; things; RFID; multi-agent

1. Introduction

Many of the errors occurring in healthcare are related to the lack of availability of important medical information about the patient. A widely recognized source of inefficiencies of the healthcare sector is the fragmentation of the care delivery process and the poor sharing of information. Healthcare systems across EU

* Corresponding author. Tel.: +40-230-216-147; fax: +40-230-524-801.
E-mail address: cristina@eed.usv.ro

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countries are largely organised in the form of separate medical facilities. At present, these systems do not share the information related to a patient, for example. The efficient sharing of medical history information is indispensable for the effective delivery of care [1], [2].

A recent study on sick adults in Australia, Canada, Germany, New Zealand, the United Kingdom and the United States indicates that when discharged from hospital, an important number of patients from all six countries did not get any information related to what symptoms to look out for and/or had no follow-up visit arranged 0. The conducted studies show some of the effects on the patients are confronted with, alongside their caregivers and families due to the lack of adequate and timely exchange of medical information. Furthermore, many studies also indicate that worldwide the coordination of care among multiple providers is often flawed, and medication errors are common [3], [4].

However, the adoption of information and communication technologies (ICTs) can change the healthcare paradigms and the way patients receive healthcare today and in the future, ensuring better care and a more efficient use of resources. The movement of healthcare out of the healthcare providers (hospital, laboratory, etc.) and into the private homes will be greatly facilitated with the latest remote sensing devices of all kinds connected to healthcare providers and care givers. The examples are numerous and the potential for cost savings and improved care is astounding.

This paper considers various enabling technologies that could be exploited in order to extend the current applications in the healthcare area. The Internet of Things (IoT) is viewed as an evolutionary process, rather than a completely new one. Thus, "from anytime, anyplace connectivity for anyone, we will now have connectivity for anything" [5]. The Radio Frequency IDentification (RFID) technology is considered to uniquely identify things (people, devices, sensors, etc. specific for the healthcare sector), that should be connected to the Internet of Things. We present various healthcare applications, considering the multi-agent, RFID and the IoT context. Lastly, conclusions are drawn in the last section.

2. Enabling technologies

2.1. Multi-agent Technology in Healthcare

Multi-agent technology proved suitable for the development of healthcare applications, where "the use of loosely coupled and heterogeneous components, the dynamic and distributed management of data and the remote collaboration among users are often considered the most relevant requirements" [6]. So far, several multi-agent systems have been developed in the healthcare sector worldwide. Next, we provide a structured enumeration of some of the most notable attempts to use multi-agent technology for healthcare.

A multi-agent system for remote healthcare monitoring through computerized clinical guidelines was developed in the SAPHIRE project [7]. This system provides a Clinical Decision Support system for remote monitoring of patients at their homes, and at the hospital to decrease the load of medical practitioners and also healthcare costs. Also, the system aims to reduce human error in hospital events/complications and finally to provide a feedback system for medical staff in training.

K4CARE [8] is a research project whose main objective was to create, implement, and validate a knowledge-based healthcare model for the professional assistance to senior patients at home. The main step of the project was to develop a healthcare model to guide the realization of an integrated system of healthcare services for the care of the elderly, the disabled persons, and the patients with chronic diseases [6].

Also, in healthcare sectors, there are proposed various medical systems that cooperate with each other. Thus, in [9], the authors propose a cooperative medical diagnosis multi-agent system called CMDS (Contract Net Based Medical Diagnosis System). This system can solve flexibly a large variety of medical diagnosis problems.

2.2. RFID Technologies in Healthcare

According to various studies and reports, RFID technologies provide numerous solutions for the main areas of healthcare industry. Thus, e.g., the Kalorama Information report, The Global Market for RFID in Healthcare, considers the market for RFID opportunities in the healthcare industry, focusing on five market segments: 1) pharmaceutical/blood product distribution and tracking, 2) patient/medical staff identification and tracking, 3) medical asset tracking and locating, 4) implantable device RFID use, 5) other areas (including medical documents and patient records) [10].

Fisher and Monahan [11] reports that many hospitals have begun to implement RFID applications in order to track inventory, identify patients, and manage personnel. In particular, various RFID applications have been used to verify patient identification in order to avoid medical errors, and collect data on workflow to find inefficiencies in hospital operations. However, they emphasize the concerns expressed by hospital staff, especially nurses, regarding the surveillance potential of these tracking technologies.

Next we present some RFID-based systems that are already successfully implemented within worldwide hospitals [12]. RFID technology is used to increase efficiency and safety in the management of the transfusion process in Italy's National Cancer Institute in Milan and Ospedale Maggiore hospital in Bologna. At Jacobi Medical Center in New York, nurses use a Tablet PC to match the RFID tags on patients' wrists with bar-coded information on packets of medication. The match ensures that each patient receives exactly the right dose and only the medication that has been prescribed to him or her. Southern Ohio Medical Center has deployed the Radianse Reveal Asset Tracking platform to increase its efficiency of asset and equipment tracking.

According to Gartner forecasts, healthcare and pharmaceutical industries will adopt RFID faster than other application domains [13]. Also, various studies (e.g., BRIDGE project [14]) estimate a significant increase of RFID use in the healthcare and pharmaceutical industry in the coming years.

RFID is one of the technologies that played an important role in a new paradigm, named Internet of Things (IoT). Next, we shortly present IoT and some applications in the healthcare sector.

2.3. Internet of Things in Healthcare

Literature presents various definitions of the Internet of Things concept. In this paper, we consider that Internet of Things is "a global network infrastructure, linking physical and virtual objects through the exploitation of data capture and communications capabilities. This infrastructure includes existing and evolving Internet and network developments. It will offer specific object-identification, sensor and connection capability as the basis for the development of independent federated services and applications. These will be characterised by a high degree of autonomous data capture, event transfer, network connectivity and interoperability" [15]. In fact, IoT can be simply considered as a shift in paradigm. "From anytime, anyplace connectivity for anyone, we will now have connectivity for anything" [5]. We consider the "things" connected to the IoT the following: physical entities: living (patients, medical staff, etc.) or non-living (medical sensors, smart devices, etc.) entities; information.

Currently, there are few applications of Internet of Things in healthcare worldwide. Subsequently, we will take a look at some recently published research papers dealing with the adoption of IoT technologies in healthcare.

Some IoT applications solve various problems related to the disabled. M. Domingo provides an overview of the Internet of Things for people with disabilities [16]. The author analyzes how people with various disabilities (such as, visual, hearing and physical impairments) can interact with and benefit from the IoT. Additionally, architecture of the Internet of Things for these people is introduced. In order to show the interaction of various components of the Internet of Things, different application scenarios are considered.

Internet of Things applications are also related to elderly people. L. Coetzee and G. Olivrin approach inclusion through the Internet of Things [17]. Their chapter presents IoT, its typical applications and some of its challenges in order to enable the inclusion of disabled and elderly people in mainstream society.

A.J. Jara et al. present a pharmaceutical intelligent information system to detect allergies and adverse drug reactions based on Internet of Things [18] and an Internet of Things–based personal device for diabetes therapy management in ambient assisted living [19]. These solutions were tested by a multidisciplinary group formed by patients, physicians, and nurses. The authors conclude that the Internet of Things is an interesting and promising approach for personalized health care systems in the next generation of mHealth solutions.

Researchers estimate that the Internet of Things will have many applications in the healthcare sector, "with the possibility of using the cell phone with RFID-sensor capabilities as a platform for monitoring of medical parameters and drug delivery" [20], etc.

3. An IoT-based approach in healthcare

In order to solve some of the current issues of the healthcare sector, we propose an Internet of Things-based approach. Fig 1 shows how things will be connected to the IoT.

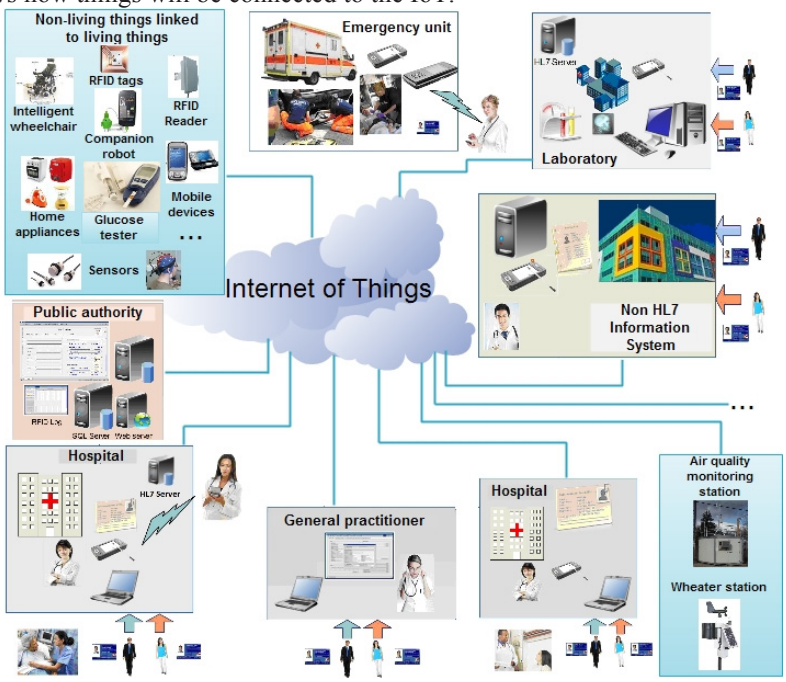

Fig. 1. An IoT approach in healthcare

Patients' electronic medical information is currently stored in many different geographical locations, such as with general practitioners' offices, hospitals and laboratories, etc. In order to gather the complete medical history information on a patient, the considered approach proposes health information exchange, rather than moving or replicating it to a giant central server.

The IoT-based approach enables the RFID-based identification of the things (patients, medical staff, medical equipments, etc.), querying and retrieving medical data from various existing healthcare information systems, as well as showing significant information to the authorized people (such as, general practitioners). Moreover, the

application running on mobile devices gives healthcare providers the information and capabilities they need wherever and whenever they need them. Also, this approach allows tracking RFID- tagged things (living or non-living) in order to provide new quality services for the mobility of patients, medical staff, medical equipments, and other things.

In order to assure the identification of things connected to the Internet of Things, we consider the use of RFID tags for: a) Tagging non-living things, such as medical equipment and instruments (e.g., wheelchairs, medical sensors); b) Tagging living things, such as patient, medical staff, etc; c) Tagging non-living things linked to living things, such as medical equipment and instruments being used by patients, visitors or staff (e.g., wheelchairs, medical sensors).

This approach ensures the positive patient identification (PPI) within a medical facility. Furthermore, it extends patient identification across medical facility boundaries, for example, through the use of a specialised agent that implements a specific information sharing protocol. Hence, the adoption of multi-agent based solution enables an easy integration with existing medical information systems.

In an Internet of Things approach, data are based on the things. Thus, these data can include the real-time data coming from the things connected to the IoT (like medical sensors, measuring equipments, weather sensors, etc.). By implementing this new concept in the healthcare sector, new opportunities will emerge for processing the gathered data and for extracting useful information that can be used, for example, for analyses or even predictions of patients' health status.

The Internet of Things links the entities of the real world with the virtual world, thus enabling anytime, any place connectivity for anything. Hence, the IoT approach in healthcare could prove valuable in assuring the compliance with some of the right principles in healthcare: right place and right time. The Internet of Things approach, due to its ubiquitous sensors and connected systems, can provide valuable information to the medical staff and patients, and improve communication between them in order to solve some issues related to healthcare delivery. Thus, with more complete patient information healthcare providers could focus on preventive rather than reactive medicine. Hence, we can say that the Internet of Things opens new opportunities for right care, another right principle considered in healthcare.

But, although the adoption of Internet of Things in healthcare could bring great benefits, this evolution towards IoT raises some issues, among which: a) Security and privacy – there are different privacy and security standards; b) Standardization – there are different intercommunication and interoperation standards. In order to integrate all types of devices, extensible standards and protocols are required; c) Scalability – these issues are raised by large-scale deployments of things.

4. Conclusion and future developments

Worldwide the healthcare sector has recognized the value of ICTs in the delivery of healthcare. However, until recently, ICTs were limited to administrative and financial applications and played only a small role in direct care for patients. But, in the past years, there have been significant changes regarding the adoption of ICT in the way healthcare is delivered.

The proposed approach is the object of our ongoing research. These research aims to integrate multi-agent and RFID technologies into an Internet of Things platform for healthcare. For this purpose, some agents will be developed in order to integrate various things into an Internet of Things platform, to assist users in various activities on the IoT platform, etc. All of them must be developed based on personal preferences. Security is a critical requirement for this approach, both user concerns and legal regulations having to be taken into account. We consider that the Internet of Things could address the emerging needs of patients and healthcare providers, at a reasonable cost, by using today's healthcare systems and existing structures. It is our objective to demonstrate the strengths and weaknesses of our multi-paradigm approach for the Internet of Things development applied in healthcare.

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