IoMT based Pill Dispensing system

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Abstract— With the growing pace of the medical industry new techniques and methodologies need to be implemented. Internet of medical things (IoMT) has been on the rise as it provides medical services , smart architectures, an enhanced platform for the doctors, hospitals and patients to interact and produce better healthcare levels. In this paper we develop a multilayer architecture sensing and collecting data regarding the patient's vitals. Then it relays the information to an android app and alert is produced in case of any anomaly in the data recorded. Based on the data and specific settings the dispenser is activated and care has been taken to ensure that the pill dispensed reaches the patient. The prototype has been built and tested to illustrate the smart connected society.

Keywords—IoMT, ambient assisted living, dispenser, sensor network, real-time

I. INTRODUCTION

Thousands of people out there suffer from health issues either fatal or minor as they have limited access to proper health care facilities like hospitals, pharmaceuticals or health monitoring establishments. Due integration with IoT, health monitoring has expanded its boundaries and now patients present in remote locations can be monitored and proper medication can be arranged for them. Systems can be constructed that monitor the patient, provide consultation in remote locations and transmit data to the providers of health related activities[1]. Various sensors can be integrated on a single prototype and can be attached to the person's body to gather the necessary information in order to monitor the smooth functioning of the person's vitals.

The ageing population has been growing at a drastic rate and according to the world health survey the population in 2030 above 65 will constitute about 17.5% of the total population[2,3]. This alarming increase requires imperative actions to be taken to cater to the needs of the elderly population. Ambient assisted living has been a major field due to the promised potential it offers to support the elderly and promote healthcare in general. AAL makes it possible for feasible and uninterrupted functioning of people hence ensuring a easy and safe lifestyle for them and those around them.

IomT facilitates all the key aspects of AAL and enables remote health monitoring as it integrates IoT enabled devices and medical equipment to form a network. RFIDs use the radio frequency tags to identify real objects, and a RFID sensor transfers data between a reader and an object which is identified track and categorize[4]. RFID can use two different types of tags: Active and Passive.

In this article we address the major health related readings and integrate all the sensors in a single unit prototype. Further a pill dispenser has been designed that tackles the problem of ill timed medication and reduces human error thus accomplishing the idea of error free medication system. The implemented secure IoT based health monitoring unit guarantees efficiency and secure monitoring and dispensing. Medication errors may occur due to human interaction while dispensing, prescribing or even during diagnosis. Prescription errors account for nearly 50% of all the errors. Errors may also occur due to administration or rigid schedules of medication. Automation provides flexibility of schedule and reduces chances of human error to a great extant[5]. A review estimates that around 25% of the elderly population do not follow their medication routine properly which may lead to poor health and drastic health issues[6]. These kind of flaws and negligence can be eradicated with the help of technology. IoT provides the basic framework and possibility to form a web of sensors, applications, actuators, devices and alert systems along with the internet to form a reliable network with a global infrastructure[7]. E-Health services have been gaining popularity considerably in the past few years and attempts have been made to integrate wearable devices to achieve promising results[8,9]. One of the major issues in IoT based healthcare is the compromised security. The patient data once collected by the healthcare service provider is no longer in control of the patient. The provider can share that data with doctors, health insurance companies and pharmaceutical companies. Hence data of the patient needs to be prevented from unauthorised access as it is not only the right of a patient for medical privacy but this may lead to various adverse health effects like depression, mental disorders hence protection of user data is extremely important and must be the upmost requirement "in press"[10]. Looking at the present scenario a huge part of the population owns mobile phones, tablets or portable means of communication[11]. Majority of the leading hospitals worldwide are equipped with wireless networks like WLANS and Wi-Fi this allows the doctors, the patients and the administration to easily access the information and to stay connected. The portable communication systems are usually equipped with formats capable to display and record electronic data, this can form the basis of home tele-consultations, monitoring and personalised medication.

II. RELATED WORK

This section discuss the literature of IoT based remote healthcare systems. A healthcare system most commonly seen in hospital is proposed in[12]. This incorporates a node attached to the patient's body which transmits the health status of a patient to a central monitoring system. Shu-yuan Ge et al. depicts a design which is basically integration of 11073 IEEE Service/DIM and CoAP to apply on devices of healthcare so they can be used in IoT settings. They have also performed a performance comparison between Both HTTP and 11073 DIM with the help of CoAP. It also evaluates the performance with CoAP and HTTP with respect to packets abundance in single transaction, packets loss rate and syntax by using JSON and XML. They concluded that CoAP transmits lesser packets as compared to HTTP. Further they concluded that XML is not better than JASON in terms of resource consumption. [13]. Iuliana Chiuchisan et al. present an intelligent system for the parkinson's infection test. His proposed system not only supports but also assists the doctors in the medical treatment, diagnosis, Prescription and overall progress[14]. Georges Matar et al. proposes a technique that monitors the patient's posture by using patient body weight which is exerted on specially designed mattress, the measured pressure is used to monitor the patient's posture. His work has been ensured and verified by Cohen's Coefficient, the value of the coefficient is .866 which means high accuracy of detection. He claims the purpose of his work is to reduce storage and cost[15]. In [16] the authors propose UDA-IoT system which is used in case of emergency. This system collects, integrates and interoperates data in various medical applications. Kuo-hui yeh et al. the advancement in the communication brings new era of IoT which is based on networks. The author proposes an IoT based system that uses body sensor networks as the ground work for efficiency and robustness especially for public networks based on IoT. The system is kept secured by proposing a security parameter[17]. Granados et al. [18]. proposes web enabled gateways for health cased IoT systems. As the wired gateways provide high efficiency and lower cost, the author installed wired gateways in areas of restricted movement. Radio frequency identification (RFID)-based e-Healthcare systems are proposed in [19,20]. In [19], the authors proposed a system to monitor the patients environmental conditions like temperature, humidity with the help of RFID, then this data is transmitted to the cloud for a more comprehensive study of the data. Catarinucci et al. [20] proposes an IoT based architecture to monitor a patient's medical condition by using an ultra high frequency RFID. RFID applications have been on the rise and are being used for managing personal information, inventory etc. This has reduced human error while collecting data[21]. The SAPHIRE project[22] provides a system that enables less medical practitioners and provides remote monitoring to patients. Furthermore this system reduces human error and provides a feedback system to the medical staff.

III. MOTIVATION

Patient monitoring has become more feasible due to the advancements in healthcare body sensor networks. Multiple wireless technologies in healthcare have been proposed which provide continuous and reliable patient monitoring in a multitude of locations. As we can see in all the above related work automatic patient monitoring has been enabled to provide the patient a high quality of healthcare and reduce the chances of anomalies. This project focuses on providing cost effective, time bounded and low power prototype. Most importantly the data is secure and can only be viewed by authorised personnel as the data maybe used in critical applications, although the challenges in security have not been challenged in depth in the past and this fact inspires us to propose the desired system. Our paper tries to reduce misjudgement of data as it involves the direct consultation of a doctor and only upon his/her approval will the data be considered validated. Moreover the dispenser upon activation does not just dispense a pill, it has a two stage verification process. At the first stage it makes sure that the patient identity is verified and only then is the ultrasonic sensor activated. At the second stage of verification the ultrasonic sensor remains active for a fixed period of time but only allows dispensing when the patient brings his hand under 10cm distance of the sensor. To make sure that no random movement near the sensor is able to deceive the mechanism, the complete dispensing unit is mounted at a wall at a height which enables a disturbance free environment.

IV. PROPOSED MODEL

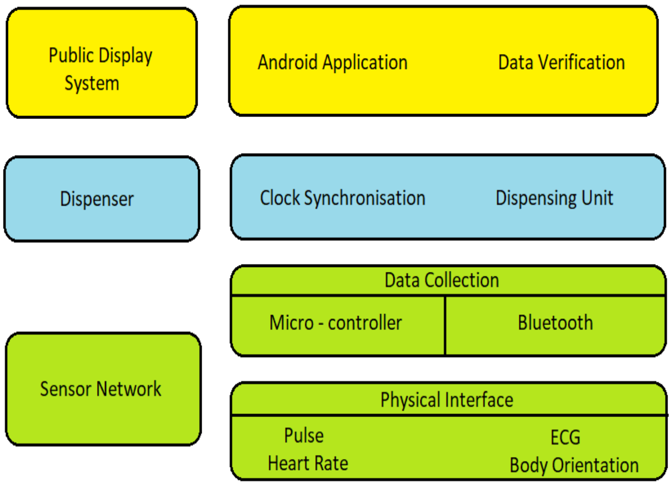

Fig. 1: Proposed IoMT architecture

The healthcare model proposed in this paper has a multilayer architecture (3 layer) as shown in Fig. 1. The architecture consists of 3 layers: sensor network, dispenser, public display. In this section we discuss each and every layer separately.

A. Sensor Network

The sensor network is the central layer and the origin of information collection of the health monitoring system. This layer collects the data which is aggregated to be transmitted to the next layer. It is like the front end of any website. The sensor network layer can be divided into two sub layers:

1) Sensor interface

A set of sensors are employed to collect the patient's vitals and monitor the surroundings. The sensor interface consists of multiple contact sensors which are of high importance to the medical industry and medical professionals and are used to assess health care consistently.

- *Pulse sensor*
  This sensor is responsible to monitor the pulse of the patient. The pulse if the number of times the human heart beats in one minute. It is based on the principles of optoelectronics. The sensor includes 2 sides , on one side we have an LED along side an Ambient light sensor and on the other side the circuit responsible for noise cancellation and amplification.

- *Heart rate sensor*
  This is a more sophisticated version of the pulse sensor which measures the heart rate by using an LED and a phototransistor. The phototransistor is responsible for detecting the flux change when a finger is placed in between the LED and the photo transistor.

- *Electrocardiogram sensor*
  This sensor is responsible to measure the heart's electrical activity. This can be stated as the electrocardiogram. This is important to understand the physiological , emotional arousal. Multiple electrodes are used to detect the electrical activity. These electrodes are attached to the human body to collect reliable and assertive readings.

- *Accelerometer*
  This device measures the static acceleration due to gravity for tilt scene applications as well as dynamic acceleration in cases of shocks and fall. This sensor can also be used to detect if the object is in motion or in the state of rest. The sensors uses piezoelectric elements which when come in contact with a round free moveable object inside the sensor produce electric current.

- *Body temperature*
  The sensor when brought in contact with the skin can detect the body temperature and thus any abnormality related to temperature like fever or hypothermia can be detected. These sensors provide an accurate reading and can be used to replace the traditional thermometers.

2) *Data collection*

While the sensors are supposed to interact with the outside world their values need to be collected, aggregated and parsed. Microcontrollers are used in this sub-layer. The microcontroller collects the data from its attached sensors processes, parses it. This data is made ready to be wirelessly transmitted to the further layers. Microcontrollers use analog to digital converters to convert the physical analog readings into digital form. 2 different microcontrollers are used: one in sensor interfacing and one in pill dispensing and the two microcontrollers are kept in sync using bluetooth.

B. Dispenser

The pill dispenser dispenses pills as per the requirements of the patient. These requirements are pre adjusted and can be modified as per the personal need. The pill dispenser works in synchronization with a real time clock that keeps a record of the day date and time. The pill dispenser consists of 3 sub-layers: dispensing system, clock synchronisation, activation system.

- *Dispensing system*
  The dispensing system consists of a servo motor that rotates as per the pre-decided angle in order to open the dispenser and dispense a pill. The dispenser is mounted on the servo motor with a hole in the bottom. The hole and the dispensing cavity are to detachable parts and free to move. As the servo rotates it rotates the base of the dispenser which has an outlet for the pill to come out.

- *Clock synchronisation*
  The real time clock is responsible for the complete functioning of the dispensing system. The clock works on a crystal oscillator and keeps a track of the day, date and time. Also the pill count is updated after each dispensing cycle. The clock synchronises the dispensing unit with the day to day activities by keeping a track of the of hours, minutes and seconds.

C. Public Display System

Our model aims at promoting ambient assistant living especially for the elder section of the society who are not able to freely roam around and have difficulty in performing the basic physical tasks of day to day life. Keeping this in mind we developed an android application using MIT app inventor with 2 interfaces.

- *Patient interface:* This enables the login into his details and access his data, furthermore to authorise the process radio frequency identification tags have been provided for the users to login and communicate with the application.

- *Doctor interface:* The doctor can access his/her patients profiles. The profile as in case of the patient interface contains all the details of the patient and the necessary vitals required for the doctor to examine and send a diagnosis in case of emergencies.

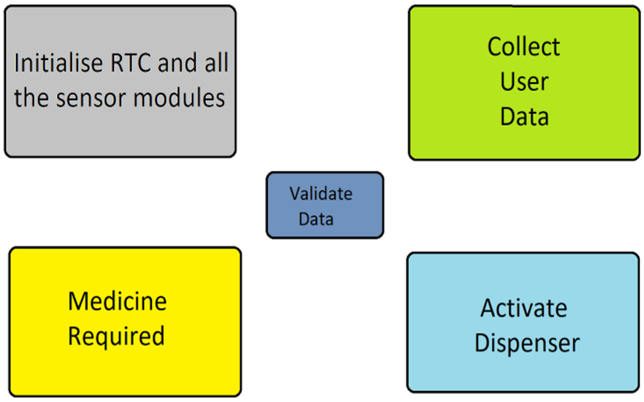

Fig. 2: Stages of the proposed system

V. EXPERIMENT EVALUATION

In this section we depict the evaluation of the implemented prototype.

TABLE I: Prototype Components

Device	Model
ECG Sensor	AD8232
Accelerometer	ADXL345
Temperature Sensor	LM35
Pulse sensor	M212
Real time clock	DS3231
Reader writer module	RC-522 RFID
Ultrasonic sensor	HC-SR04
Bluetooth module	HC-05

A. Pulse and heartbeat monitoring

The patient is present in a calm and composed state for a the first few seconds after commencement of the experiment and later begins to spot jog and perform basic exercises and a rise in the heartbeat is noted upon increased physical activity and it fluctuates depending on the physical activity. The threshold for alerting the dispenser is set at 95.

B. Fall detection

Here the fall detection capability is tested. In this experiment the patient walks freely and then purposely drops down multiple times to check the fall detection. Upon falling the sensor detects acceleration only in the z-axis and all the other axis are still. The fig depicts the fall detection by graphing the acceleration due to gravity against time. The acceleration only changes when the patient falls but remains constant otherwise.

The fall detection graph is shown in Fig. 3

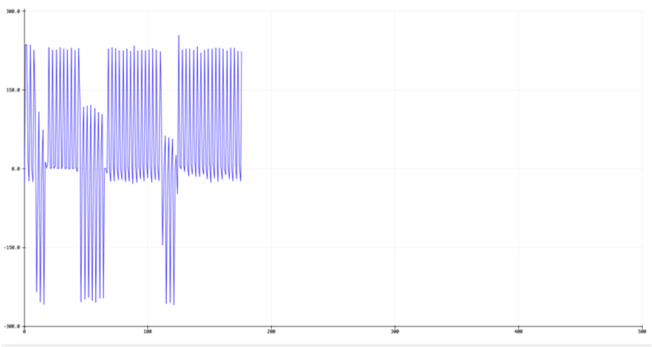

Fig. 3: Fall detection

C. *Electrocardiogram activity*

Next we measure the ECG for the patient, ECG health electrodes are attached on the patient's body each on his hands and an electrode on his lower abdomen area. ECG records the rhythm of the heart and the peaks and dips can be interpreted by the doctor to check for any sort of abnormal activity. The patient is kept at rest and the patches are attached to the body to detect the electrical changes in the activity of the cardiac muscles of the patient. The figure depicts the electrocardiogram of the patient's heart. The electrocardiogram activity of the heart for the patient under observation in shown in Fig. 4

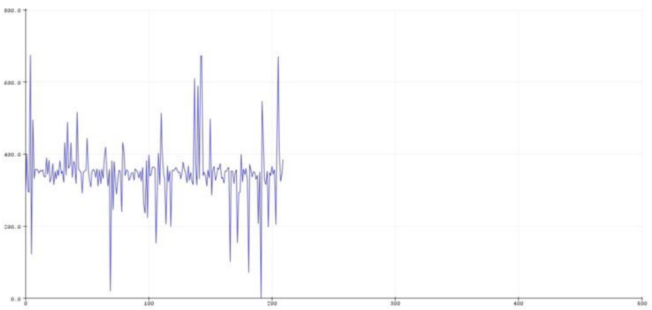

Fig. 3: Electrocardiogram activity

D. *Temperature*

The temperature of the patient is measured, the temperature sensor is brought in contact with the patient's body for a short time interval and the reading is noted. The readings are noted multiple times during the day and the results are recorded. The threshold for alerting the dispenser is set at 38 degree Celsius.

While the pulse and temperature are recorded and reading surpassing the threshold in any of the readings activate the pill dispenser.

TABLE 2: Simulation Readings

Simulation	**BPM (pulse)**	**Temperature (in Celsius)**	**Time**
S1	82	36.4	08:20
S2	99	38.2	09:30
S3	87	37	11:00
S4	87	37	12:00
S5	92	37.3	13:10
S6	88	37.1	14:30
S7	87	36.4	15:50
S8	93	37.8	17:30
S9	98	37.8	18:30
S10	84	37	19:50

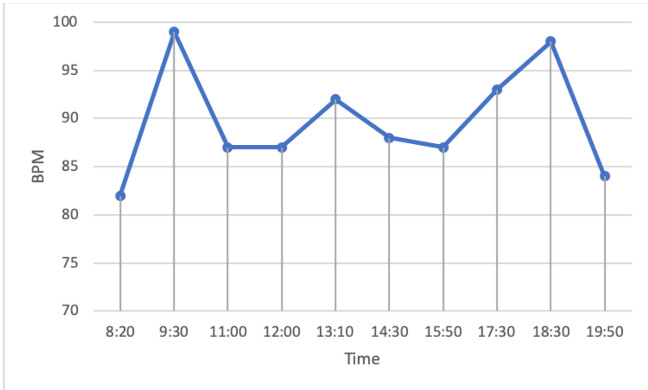

Fig. 4: BPM Variation

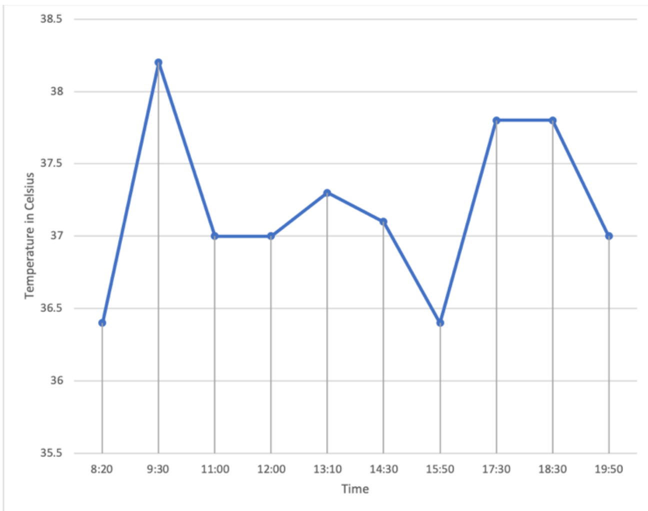

Fig. 5: Temperature Variation

Ten readings were taken during a fixed interval of time and the reading have been plotted.

TABLE 3: Distribution of medication error

Examples of Error	Stage	Type of Error
Variation in composition salts	Pill Segregation	Brand Name
Wrong Pill dispensed	Administration	Compartment Miscalculation
Misplaced RFID tag	Authorisation	Personalisation
High Potency Dose	Administration	Automation
Skipped dosage	Administration	Dosage

VI. CONCLUSION

The elderly population requires intensive and extra care as compared to the rest of the population. The paper presents a IoMT based platform for the overall monitoring and ambient assisted living (AAL) by deploying a multilayer architecture (3 layer). The sensors used may produce results that may vary overtime, hence they either need to be replaced or calibrated in order to produce the most accurate results even after usage over a long period of time. As the process involves the consultation of a doctor the whole process can be delayed due to human interaction. The different sensors involve different delay times to be used in order to display the readings, the prolonged display of continuous real time readings cause an error in the parsing of data. Continuous use of hardware may cause heating of the equipment and may lead to temporary shutdown. The results of the tested prototype have been attached to conclude that the presented experiment stands by the requirements of AAL and satisfies the needs of the target population or anyone using the prototype.

REFERENCES

[1] H. Fang, X. Dan, and S. Shaowu, "On the Application of the Internet of Things in the Field of Medical and Health Care," in Green Computing and Communications (GreenCom), 2013 IEEE and Internet of Things (iThings/CPSCom), IEEE International Conference on and IEEE Cyber, Physical and Social Computing, pp. 2053-2058, 2013.

[2] World Health Organization, World report on ageing and health, 2015.

[3] M.Aminian and H.Naji,"A hospital healthcare monitoring system using wireless sensor networks," J. Health Med. Inform, vol. 4, no. 02, 2013.

[4] M. Kärkkäinen and J. Holmström, "Wireless product identification: enabler for handling efficiency, customisation and information sharing," Supply Chain Management: An International Journal, vol. 7, (pp. 242-252), 2002.

[5] Koppel B, et al., "Role of Computerized Physician Order Entry Systems in Facilitating Medication Errors," Journal of American Medical Association, Vol. 293, No. 10, 2005.

[6] S. Li, L. Xu, and X. Wang, "Compressed Sensing Signal and Data Acquisition in Wireless Sensor Networks and Internet of Things, " *IEEE Transactions on Industrial Informatics* vol.9, no.4, (pp. 2177-2186), Nov. 2013.

[7] G. Kortuem, F. Kawsar, D. Fitton, and V. Sundramoorthy, "Smart objects as building blocks for the Internet of things," *IEEE Internet Computing,* vol.14, no.1, (pp.44-51), Feb. 2010.

[8] P. Castillejo, J.-F. Martinez, J. Rodriguez-Molina, and A. Cuerva, "Integration of wearable devices in a wireless sensor network for an E-health application," *IEEE Wireless Communications,* vol.20, no.4, (pp.38-49), 2013.

[9] X.-F. Teng, Y.-T. Zhang, C. Poon, and P. Bonato, "Wearable Medical Systems for p-Health," *IEEE Reviews in Biomedical Engineering*, vol.1, (pp.62-74), 2008.

[10] M. Shamim Hossain, Ghulam Muhammad,"Cloud-assisted industrial internet of things(IIoT)- enabled framework for health monitoring" "Computer Networks," Elsevier, The international Journal of Computer and Telecommunications Networking, 1-11, (2016).

[11] Craig Feied, Neil Jordan, Meera Kanhouwa, James Kavanagh, "The New World of Healthcare Work: A Microsoft White Paper", UK Focus International Lecture, The Royal Academy of Engineering, 7 November 2006.

[12] United Nations Department of Economics and Social Affairs – Population Division., " World Population aging 2015 report," http://www.un.org/en/development/desa/population/publications, ISBN 978-92-1-057854-7.

[13] S. Ge, S. M. Chun, H. S. Kim, and J. T. Park, "Design and implementation of interoperable IoT healthcare system based on international standards," in Proc. 13th IEEE Annual Consumer Communications & Networking Conference, 2016.

[14] I. Chiuchisan and O. Geman, "An approach ofa decision support and home monitoring system for patients with neurological disorders using internet of things concepts," Wseas Transactions on Systems, vol. 13, (pp. 460-469), 2014.

[15] G. Matar, J. Lina, G. Kaddoum, and A. Riley, "Internet of things in sleep monitoring: An application for posture recognition using supervised learning," in Proc. International Conference on IEEE Healthcom, 2016.

[16] B. Xu, L. Da, H. Cai, C. Xie, J. Hu, and F. Bu, " Ubiquitous data accessing method in IoT-based information system for emergency medical services," IEEE Transactions on Industrial Informatics, vol. 10, no. 2, (pp. 1578-1586), 2014.

[17] K. Huiyeh, "A secure IoT-based healthcare system with body sensor networks," IEEE Access, Volume 4, (pp. 10288-10299), 2016.

[18] J. Granados, A.M. Rahmani, P. Nikander, P. Liljeberg, H. Tenhunen, et al., Web-enabled intelligent gateways for eHealth internet-of- things, in: R. Giaffreda, et al. (Eds.), Internet of Things. User-Centric IoT, Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering (LNICST), pp. 248–254, 2015.

[19] S. Amendola, R. Lodato, S. Manzari, C. Occhiuzzi, G. Marrocco, RFID technology for IoT-based personal healthcare in smart spaces, IEEE Internet Things J. 1 (2) 144–152, (2014).

[20] L. Catarinucci, D. De Donno, L. Mainetti, L. Palano, L. Patrono, M.L. Stefanizzi, L. Tarricone, An IoT-aware architecture for smart healthcare systems, IEEE Internet Things J. 2 (6) 515–526, (2015).

[21] Fisher, J. A., Monahan, T. Tracking the social dimensions of RFID systems in hospitals. International Journal of Medical Informatics, 77, (pp. 176–183). (2008).

[22] Laleci, G.B., Dogac, A., Olduz, M., Tasyurt, I., Yuksel, M., Okcan, A. SAPHIRE: A Multi-Agent System for Remote Healthcare Monitoring through Computerized Clinical Guidelines. In R. Annicchiarico, U. Cortés, C. Urdiales, (Eds.) Agent Technology and e-Health. Whitestein Series in Software Agent Technologies and Autonomic Computing, Babel, Switzerland: Birkhäuser V erlag, (pp. 25-44) ,(2008).