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IoT based Smart and Pervasive ICU for ImprovingIntensive Health Care

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Abstract— *Setting up a smart and pervasive environment is one of the current challenges being investigated in several research topics. Among the panoply of applications enabled by the Internet of Things (IoT), smart and connected health care is a particularly important one. Networked sensors, either worn on the body or embedded in our living environments, make possible the gathering of rich information indicative of our physical and mental health. Design a smart intensive care units is an original idea and a recent research topic which is tackled in this work. First, in this paper, we highlight the opportunities and challenges for IoT in realizing this vision of the future of health care and then, it is devoted to attainment of new patient monitoring intelligent system in ICUs in order to improve medical care service performance. We offer through this work, an hybrid architecture over a single platform for a visual patient monitoring system for Automatic Detection of risk Situations andAlert (ADSA) using a multi-camera system and collaborative medical sensors network.*
Keywords—*Smart and Pervarsive Health System, Internet Of Things (IoT), Medical Sensors Netwoks, Patient monitoring in Intensive Care Unit (ICU).*

I. INTRODUCTION

Information and Communication Technologies solutions for modern healthcare systems continuously grow worldwide. Recent years have seen a rising interest in wearable sensors and today several devices are commercially available [1] for personal health care, fitness, and activity awareness. In addition to current smart medical devices, researchers have also considered applications of such technologies in clinical applications in remote health monitoring systems for long term recording, management and clinical access to patient's physiological information [2], [8]. Based on current technological trends, one can readily imagine a time in the near future when your routine physical examination is preceded by a two–three day period of continuous physiological monitoring using inexpensive wearable sensors.

The work developed in this paper focuses on the study and the development of an intelligent patient monitoring system in medical environment. Indeed, one of the specialized sections of a hospital that are Intensive Care Units (ICU) are of great importance because of the seriousness of the health status of patients staying and therefore need special attention. Due to the severity of patients treated in the intensive care units, these units are commonly equipped by a variety medical-equipment that is handled a multidisciplinary medical team in order to monitor ICU's patients in real time. In addition, we find, nursing staff, the monitoring and life support devices necessary to provide continuous care to patients that are severely ill and medically unstable. The latter receive special care and are monitored in real time by the medical team through a breathing assistance system and the decision-making support that is, for instance the ECG. To help the patient to stay alive, a partial or total ventilator support is mandatory depending on the severity of the condition in which the patient is located. It appears of course that, the respiratory support justifies a significant monitoring system in ICUs that is very particular and intricate. Faced with these requirements, the limits of the performance of these systems are obvious. The shortcomings of the current patients monitoring system in ICU are well established. They were the subject of a thorough study well supplied in the state of the art [3]. Among many limitations, we have:

- A very alarmist monitoring system [3] with a significant rate of false alarms that hinder the tranquility of the patient;
- Critical lack of relevant visual data describing the behaviors and the conditions of patient;
- Inexistence system of a centralized management of the different types of data processed by doctors to help efficiency in decision-making support mechanism;

In order to attempt answer those identified issues, a review will be performed on the importance of smart and connected health care using Internet of Things. This review will be carried out in order to identify the causes of the inefficiency of health care in ICU to propose appropriate solutions for improving the ability of a better decision making, which should result in a better overall treatment. We designed an intelligent and ubiquitous system for the patient monitoring in ICUs. This system called ADSA (Automatic Detection of risk Situations and Alert) [3] is based on IoT-architecture including a multi-camera system and cooperating medical sensors network. The main contribution of this work is the implementation of a new unifying architecture of several wireless technologies. In addition, we have set up a decision support tool to store and interpret the data collected. A physical organization as well as the logical architecture is proposed for the novel patient monitoring system.

The remaining part of this paper is organized as follows. Section II is devoted to IoT use case of E-Healthcare Solutions. In Section III, we outline the architecture for remote health monitoring systems based on smart wearable sensors, partitioning the system into for main components data collection network, analytics, and decision making. In Section IV, we highlight the opportunities and challenges related to each of these components. We conclude the paper in Section V with a summary and discussion.

II. USING IOT FOR E-HEALTHCARE TO DESIGN UBIQUITOUS ICU

The Healthcare industry remains among the fastest to adopt the Internet of Things. The reason for this trend is that integrating IoT features into medical devices greatly improves the quality and effectiveness of medical-service, bringing especially high value for the patients with chronic conditions, and those requiring constant and real time monitoring. The IoT is the network of physical objects that contain embedded technology to sense and communicate, to interact with their internal states or the external environment. IoT is at the confluence of efficient wireless protocols, improved sensors, cheaper processors and a bevy of start-ups and established companies developing the necessary management and application software, thus making this concept of the Internet of Things mainstream [4]. According to industry analyst firm IDC (International Data Corporation), the installed base for the Internet of Things will grow to approximately 212 billion devices by 2020, which includes 30 billion connected devices.

III. PROPOSED SYSTEM ARCHITECTURE FOR SMART-ICU

In this section, we describe an improved patient monitoring system through the establishment of an automatic medical data gathering system in real-time and analysis in order to assist clinicians in decision making in ICUs. For this, we propose a system with architecture in three layers that are:

1) Physical layer that takes into account all radio specification and the organizational structure of data collection networks (kinds of sensors, physical architecture of data collection network, transmission technology, network topology and coverage);

2) The logical layer is responsible for media access management protocols in the network. It also handles inter- sensor communications including the request management such signaling messages between the different sensors to ensure cooperation or collaboration function for efficient data transmission and optimization of energy consumption in the network;

3) The application layer provided all support services to healthcare personnel in decision-making. Among many other services available locally on the site (hospital) and across the web (using IoT services), we have the intelligent storage (using big data technologies), automatic data indexing and analysis, support tools decision making.

The remainder of section is dedicated to present the various layers while pointing out the associated features with each layer. Figure 1 illustrates the proposed system architecture for a remote health monitoring system.

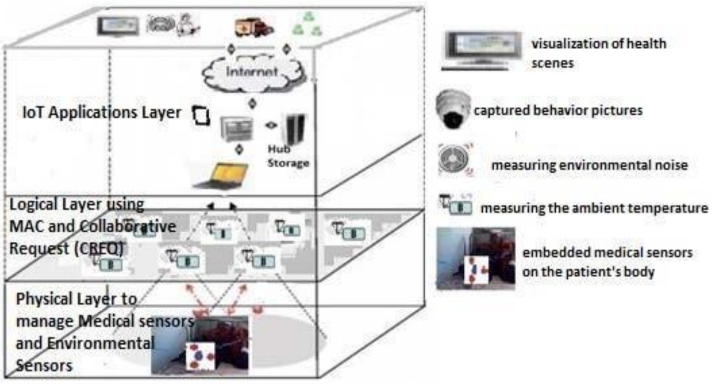

Fig. 1. Global layered architecture of the proposed system

A. *Physical layer*

This layer defines the characteristics of sensors used. We used two broad categories sensors. We have, on the one hand, medical sensors to measure physiological parameters such as the patient's body temperature, blood pressure, heart rate via ECG whose interconnection is the medical data collection network [9]. On the other hand, we have environmental sensors to enable them to measure the parameter values related to the environment in which the patient resides. It has been proved by hospital physician medical environment influence for many the condition of the patient in intensive care. Among these environmental sensors, we have cameras that record the behavior of actors in the intensive care unit (doctor and patient), sensors for measuring the ambient temperature of the treatment room, measuring light measurement noise (noise Audible medical equipment patient monitoring) and display screens of video scene in care room with light (yellow and red) by alarm monitoring office to inform doctors of the detection of a risky situation for the patient [3]. As for the used physical architecture, the network topology, the transmission technology and the network coverage, they are organized according to level of service. In this context, three services levels are defined and concerned: the level of medical patient data collection service, the level of environmental data collection service and the transfer service level data measured at the processing servers.

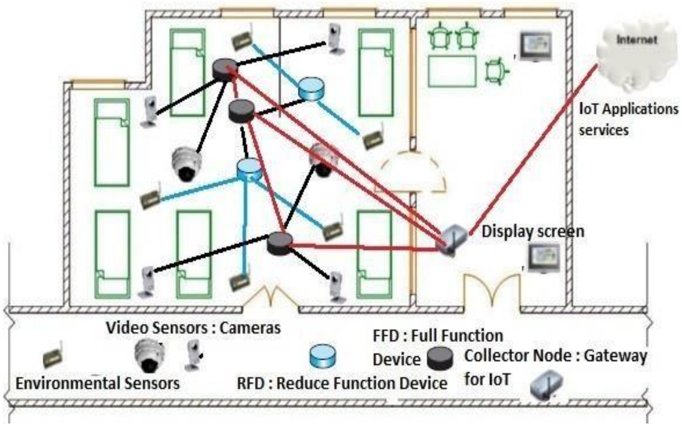

Fig. 2. Physical architecture of proposed system

Level 1*: medical data collection service*

Most proposed frameworks for remote health monitoring leverage three tier architecture: a Wireless Body Area Network (WBAN) consisting of wearable sensors as the data acquisition unit, communication and networking and the service layer [2], [5]–[6]. For instance, propose a system that recruits wearable sensors to measure various physiological parameters such as patient's body temperature, blood pressure and cardiac rhythm (ECG) [1]. Medical Sensors transmit through a Bluetooth connection the gathered information to a cluster head node. The latter uses a hybrid interface as Bluetooth and ZigBee to communicate with medical sensors and gateway node. Furthermore, we use a flexible on-site, ad- hoc architecture data collection is based on IoT and distributed sensors. Each sensor is identified with RFID technology for authentication security service using IoT-Infrastructure software through the servers responsible for services such as sensor and user authentication (LDAP directory tree) and a private domain name server (DNS) system.

Level 2*: environmental data collection service*

Account held constraints, firstly the volume and quantity of environmental data (accordingly of their nature: images and sound, for example) to collect and transmit, and secondly, their production rate (generation rate), it seems sensible to use a light and flexible network technology that offers speeds adapted to these constraints while meeting frequency wave emission standards in the medical environment. Based on a study of existing for wireless transmission technologies, our choice was made on the ZigBee due to many advantages.

In addition, energy limitation of these devices necessitates the use of suitable low power communication protocols, as the communication can account a significant part of the power consumption in sensing devices. ZigBee over IEEE 802.15.4 is commonly used in low rate WPANs (LR-WPANs) to support communication between low power devices that operate in personal operating space (POS) of approximately 10m. ZigBee provides reliable mesh networking with extended battery life. Bluetooth low energy (BLE) is another wireless communication protocol suitable for low power short range communication suitable for the unique requirements of applications such as health monitoring, sports, and home entertainment [1]. Thereby, environmental sensors are equipped with an 802.15.4 interface that allows them to exchange with a gateway node 802.15.4. The devices combine these environmental sensors transmit information through an ad hoc architecture to an FFD type ZigBee node playing the gateway for redirect traffic to a different technology network. See the appended figures, environmental sensors used in the context of the implementation of our experimental system in hospital.

***Level 3**: data distribution for remote processing servers*

The remote network distribution of collected data by our proposed system to the storage and processing servers to help the physician in decision making can be any wireless transmission technology of wide area network (WWAN) such as GSM, UMTS, WiMAX and VSAT. In our system architecture, we propose a federator-network technologies WLAN and WWAN. For coverage across the LAN, the WIFI technology that can be extended as hotspot in 802.11 standard M5 NanoStation range. Otherwise, WiMAX technology (802.16 standard) is used for extended interconnection. For instance, when the transmission is in the same hospital or hospitals in the same area, we use an interconnection WIFI hotspot and if not, WiMAX is used.

B. Logical layer

In the concern to ensure the efficiency of the system and an efficient data transport through our hybrid network technology, we offer a mechanical quality management logic data transmission level transport. The logical layer includes two sub-layers to manage logical process in the network. In doing so, we distinguish the LLC sublayer and the MAC sublayer as defined in the 802.15.4 standard. The Medium Access Control called MAC-layer is defined by the 802.15.4 standard. The MAC data service is responsible for the transmission and reception of the MPDUs through the physic data service. The MAC layer management service, if the device is a coordinator, manages the network beacons. It is also responsible for PAN association and disassociation, frame validation, and acknowledgment providing "a reliable link between two peer MAC entities." The media access is managed at MAC layer and is using the CSMA/CA for channel access and handles and maintains the GTS mechanism. It also supports device security. To better ensure the transport during the data transmission. The information flow is separated into two main categories namely: the flow of traffic Videos Basic (TBV), which represents the multi native video media stream and stream videos Traffic Controls (TCV), which represents the information to be exchanged between video capture sensors (cameras). Only high-level information transmitted between network nodes. All treatment is distributed via a system of perception of vision to Centro- Distributed hybrid architecture. On one hand, the low level processing includes the detection, monitoring local and classification of objects that are implemented using an integrated application embedded in freeware in an internal memory of smart cameras and distributed locally through the different cameras. In total, the cameras belonging to the monitoring network will exchange specific information and command them by exploiting the TCV type of trade channels to cooperate and work together to improve the analysis and interpretation of the video scene.

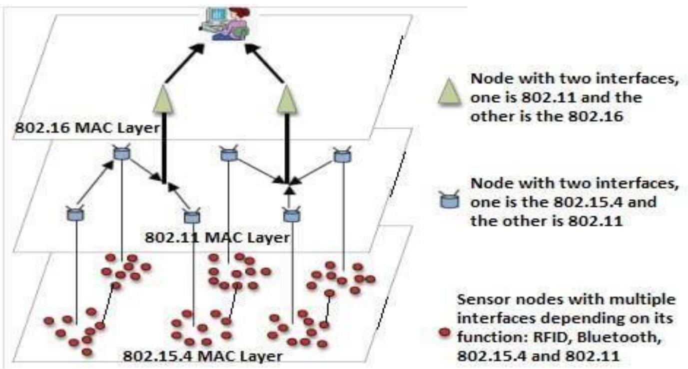

Fig. 3. Logical architecture and software organization of proposed system

C. Application layer

Application layer enables to manage all applications to assist the clinician in the phase of decision making. Such applications include the storage, indexing and analysis of environmental and patient physiological parameters measured and also interesting images of clinical scenes or important behavior of the patient. For instance, we have the establishment of a medical database named Medical Black Box (MBB). The role of the Internet of Things is becoming more prominent in enabling access to devices and machines, which in medical monitoring systems is very helpful. This evolution will allow the IT to penetrate further the digitized patient monitoring systems in ICU. The IoT will connect the hospital to a whole new range of applications, which run around to improve medical quality of service in ICU. The storage system is based on Big data solution (Casandra for instance) in IoT context and is designed for long term storage of patient's biomedical information as well assisting health professionals with diagnostic information. The intelligent video monitoring system [8] helps to manage, to analyze, to index and retrieve the information from the IP video stream. The aim of this system is to extract good visual content representative key-frames. In order to achieve this, we used an efficient method for human activity recognition in medical videos which leads to the extraction of better key-frames as representative (interest scenario) for important events summary [7]. The MBB is a database containing interesting images obtained by video selection which represents the summary of critical or important events from hospital stay [3].

IV. BENEFITS OF SMART AND PERVARSIVE ICU

The proposed system for improving medical service in Intensive care units is a new and original idea that plugs into the current growing need world with increasingly intelligent systems. The solution not only reduces transmission delay of physiological vital signs but also improves its bandwidth utilization. The role of wireless technology in healthcare applications is expected to become more important with an increase in deployment of mobile devices and wireless networks. This new technology has potential to provide many advantages to patients, medical staff, and society at large through continuous monitoring of various physiological vital signs and provide real-time feedback to the user and the medical staff. Smart ICU can enhance care in manydirections:

- facilitate an evolution in the practice of intensive medicine to a proactive framework for prognosis of diseases at an incipient stage, coupled with prevention, cure, and overall management of health instead of disease,
- enable personalization of treatment and management options targeted particularly to the specific circumstances and needs of the individual,
- help reduce the cost of health care while simultaneously improving outcomes and improve significantly the monitoring system in ICU.

V. CONLCUDING AND REMARKS

In this paper, we highlight the opportunities and challenges for IoT in realizing this vision of the future of health care. Indeed, the intensive care unit is a great example whose need for smart system becoming unavoidable. In this paper, we succinctly reviewed the current state and projected future directions for integration of intelligent remote health monitoring technologies into the clinical practice of medicine. In this sense, we proposed a smart and pervasive ICU using an architecture based on wireless sensors Based-IoT for Improving Intensive medical care. This hybrid architecture of wireless technology has the advantage of uniting in a platform for converged data transmission services for the efficient transport of medical data. Noted that there are several benefits of Smart Process Applications can have for patient monitoring in ICU like: *1)Smart functions provide accurate, transparent data on plant processes, for instance on energy usage, 2)Smart functions, collect, process and consolidate information and analyses, simplifying records and reporting processes and integrating all decision-making processes, 3)Smart functions help optimizing patient monitoring system in ICU, thereby increasing medical care quality and reducing costs.*

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