Smart Mobile Healthcare System based on WBSN and 5G

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***Abstract*—The intelligent use of resources enabled by Internet of Things has raised the expectations of the technical as well as the consumer community. However there are many challenges in designing an IoT healthcare system, like security, authentication and exchanging data. The IoT healthcare system, is transforming everyday physical objects, medical devices that surround us into an embedded smart healthcare system. Public healthcare has been paid an increasing attention given the human population and medical expenses exponential growth. It is well known that an effective monitoring healthcare system can detect abnormalities of health conditions in time and make diagnoses according to sensing (WBSN) data. This paper propose a general architecture of a smart mobile IoT healthcare system for monitoring patients risk using a smart phone and 5G. The design of multi-protocol unit for universal connectivity. Web and mobile applications developed to meet the needs of patients, doctors, laboratories analysis and hospitals services. The system advises and alerts in real time the doctors/medical assistants about the changing of vital parameters of the patients, such as body temperature, pulse and Oxygen in Blood etc… and also about important changes on environmental parameters, in order to take preventive measures, save lives in critical care and emergency situations.**

Keywords*—*IoT; multi-protocol; smart mobile healthcare system; WBSN; android; 5G

I. Introduction

With a rapid growth of human population and medical expenditure, mobile IoT healthcare becomes one of most significant issues for both individuals and governments. Meanwhile, according to a report from the World Health Organization (WHO), the problem of population aging is becoming more serious. Health conditions of aged people usually need to be checked more frequently [1], which poses a greater challenge to existing medical systems [2]. Therefore, how to identify human diseases in time and accurate manner with low costs has been paid an increasing attention [3]-[5]. Moreover in science and technology industries, it has been observed that whenever a person is exposed to overwork, it mostly leads to fatigue. If this condition continues unattended this might lead to other complications such as heart diseases and sometimes even cause a major drop of oxygen level in the body. It eventually becomes fatal for that person. Likewise, a large number of workers who are exposed to aggressive environments die due to cardiovascular diseases every year. The present world population also has an increase in the number of aged people who seek health care. The majority of them lives alone or remains inside their home. Hence, in case of emergency situations, if the patients do not get the immediate medical care, the chances of death become high. Therefore a healthcare system for monitoring the vital signs of the human body would be a smart way to prevent such situations [6]. These vital signs which include body temperature, heart or pulse rate, respiration rate, blood pressure and oxygen saturation level, are measurements of the body's most basic functions which are useful in detecting or monitoring medical problems [7]-[9]. A specific IoT healthcare system fills in this gap by acting as multi-protocol platform between public network and local WBSN with specific needs. IoT is a network of connected Things with embedded system allowing them to sense, report, control remotely and sometimes take decisions. The concept of objects with electronics connected to a network has existed for quite a while now. While the premise of connection to the Internet increases reach of IoT [10]-[12], it also poses some challenges. First challenge is that many IoT nodes have limited memory, storage and computation capabilities and are not able to connect to the IP based networks directly. Second challenge is the universality of connection protocols.

This paper aims to provide measures of physiological parameters such as body temperature, pulse rate and oxygen saturation level. The physiological data are processed using 5G, body sensors coupled to an Arduino and RasberryPi boards. The mobile healthcare system (IoT platform) is designed to gather Biometric information. This information can be used to monitor in real time the state of a patient or to get sensitive data in order to be subsequently analyzed for medical diagnosis, using an android application, web services and multi-protocol unit. The design of specific multi-protocol unit for universal connectivity of WBSN. The smart mobile healthcare system advises and alerts in real time the doctors/medical assistants about the changing of vital parameters of the patients and about important changes in environmental parameters, in order to take preventive measures, save lives in critical care and emergency situations.

The remainder of this paper is organized as follows. Section 2 describes some related works, and Section 3 explains the architecture of a smart mobile healthcare system. Section 4 discusses specific multi-protocol unit for universal connectivity. Section 5 shows the transfer of the temperature, from body sensor to the android mobile interface. Section 6 present some Android interfaces for doctors, the system advises and alerts via Android interface in real time doctors/medical assistants about the changing of patient's vital parameters. Section 7 present the study of the existing system and the different use case diagrams, the class diagram contains attributes, methods, and associations of objects. Section 8 shows the web application developed to meet patients' and doctors' needs, analytical laboratories and hospitals. Finally, Section 7 draws some conclusions and discusses some possible directions for future research.

II. Related Work

Wireless body sensor network (WBSN) may engage different technologies at different levels [13]-[18]. So many issues of researches are then opened to be studied such as energy consumption, architecture, routing solution and communication protocols. In [19], the authors propose solutions to the energy minimization problem and network lifetime maximization problem based on intelligent time and power resource allocation in WBSN context. Both problems are formulated and solved as geometric programming. In [20], the authors propose a relay based routing protocol for Wireless in Body Sensor Network. Network lifetime maximization and end-to-end-delay problems are formulated and solved with linear programming. However, No systematic scheme is proposed to address the optimal relay location consideration.

Furthermore, since the model proposed considers only routing layer, it fails to formulate a cross-layer optimization problem. Considerations on other layers, such as power control technique, are neglected. In [21], the authors propose a mathematical optimization problem that jointly considers network topology design and cross-layer optimization in WBSNs.

For comparative purposes, many works are focused on the revision of each type of health sensor and the way of communication with the server or the other sensor. Wen-Tsai Sung et al. [22] proposed a measurement system which monitors the physical condition of the users. It helps them to maintain healthy physiological conditions. These three modules (ECG, blood pressure and oxygen saturation) will record the physiological signals and then send the data to a mobile device. The system focuses upon three communication system for data transmission (RS-232, ZigBee, and Bluetooth). The data is viewed on an Android mobile device and then immediately sent to the cloud server through Internet. RenGuey Lee, et al. [23] proposed a system to prevent and control the physiological parameters affected by both chronic diseases: hypertension and arrhythmia. The system is a role-based smart mobile care system with alert mechanism. Each of these persons uses a mobile phone device to communicate with the server setup. This system uses physiological signal recognition algorithms in commercial mobile phones with Bluetooth communication capability. William Walker, et al. [24] proposed a system to monitor the blood pressure of a patient. The data has been transferred to a monitoring center using wireless sensor network. The data is displayed and stored there. The Blood Pressure data acquisition module is interfaced with a user-friendly graphical user interface. It monitors current and past measurements for all patients through wireless transmission. Zhe Yang et al. [25] propose an architecture of an ECG monitoring system based on the Internet of Things cloud. The ECG data gathered from the human body is transmitted directly to the IoT cloud using Wi-Fi.

In conclusion there are many ways to communicate with the sensors such wired link, Bluetooth, ZigBee, Wi-Fi… This paper propose to unify most of them into one specific multi-protocol unit for universal connectivity.

III. Architecture of a Mobile Healthcare System

The basic functions of a smart healthcare application include ECG waveform and display pulse and oxygen in blood [26], body temperature [27], [28], etc. Also through smart phone screen or printed paper media, indication as well as simple user interface through buttons.

More features, such as patient record storage through convenient media, multiple levels of diagnostic capabilities are also assisting doctors and people without specific trainings to understand how to use smart IoT healthcare application and their indications conditions.

Smart wireless body sensors networks are applications that measure Pulse and Oxygen in Blood. Results can be saved for future reference and track of multiple people with individual profiles can be kept, (see Fig. 1). This application has access to the following:

Wireless network communication, Full network access, allows the application to create network sockets and use custom network protocols. The android interface receives data from WBSN through Wi-Fi, ZigBee or Bluetooth, so this permission is required to send data through the Web.

The access to Bluetooth, ZigBee or Wi-Fi settings, allows the application to configure the local device, and to discover remote devices. Network allows the application to view information about network connections such as which networks is connected.

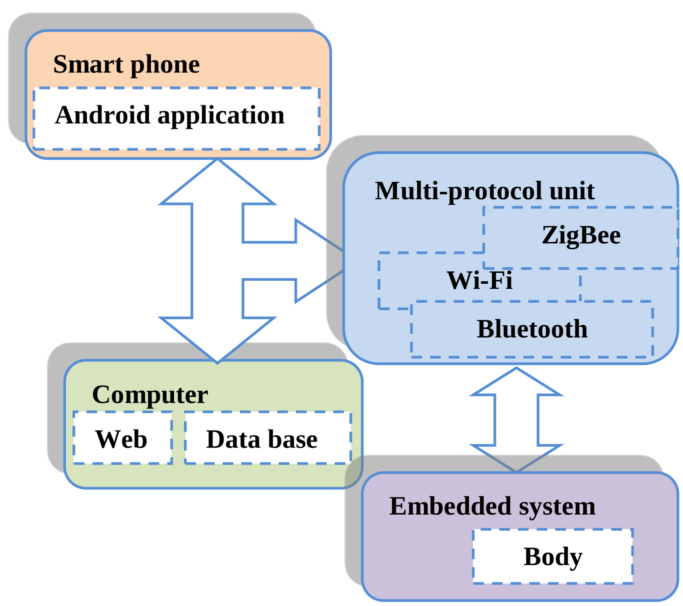

Fig. 1. Architecture of smart mobile healthcare system.

A. Specification of Requirements

It is essential to understand the stakes and the needs of the users to arrive at an adapted computer tool in the time allowed. This is the specification of the services offered to the users and provided by the system to be designed. Within this framework, two types of needs are to be studied:

- Functional requirements.
- Non-functional requirements.

Beginning by identifying the actors of our application afterwards making clear the functionalities offered to the users.

B. Identification of Actors

The actor represents the external entity that acts on the system (operator, other system ...). It can view or change the system status. In response to the action of an actor, the system provides a service that corresponds to its need.

- The doctor: It is the one who does the registration in the web application to manage his patients and to monitor remotely each one.
- The Patient: It is the Smartphone user who wants to use the mobile application in order to contact his doctor and send him the results of the medical analysis performed.

C. Specification of Functional Requirements

Functional needs or business needs represent the actions that the system must perform; it only becomes operational if it satisfies them. They express an action that the system must perform in response to a request (see Fig. 2). These are the functions, operations or transformations that the application must perform. Our application should mainly cover the functional requirements shown in the following table (Table 1).

TABLE I. FUNCTIONAL REQUIREMENTS

Actor	Functionalities
Doctor	• Authentication Management. • Profile Management. • Patients Management. • Messages Management. • Notifications Management. • Appointments Management. • Medical analysis Management and monitoring of patient. • Medical prescription Management.
Patient	• Authentication Management. • Profile Management. • Subscription Management. • Messages Management. • Medical analysis Management.

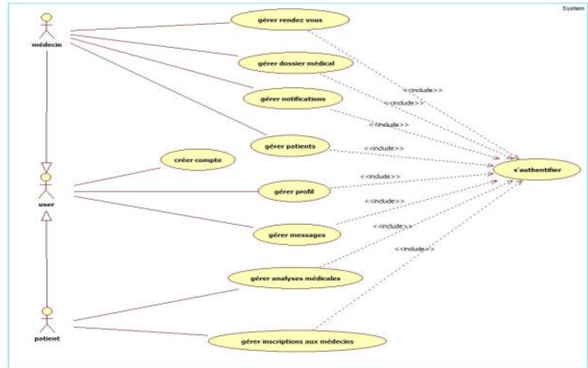

Fig. 2. Case diagram use.

IV. SPECIFIC MULTI-PROTOCOL UNIT FOR UNIVERSAL CONNECTIVITY

Connectivity is essential in any networked system. If the application is highly distributed, more than one type of protocols may be used. Such as one could use Wi-Fi or ZigBee for local network communication and use 4G or 5G for wide area communication [20]. The main function of this link is to transfer the information gathered and processed by the end node to the application software or based service. Connectivity is always in duplex form. It acts for communication between application software and local hardware. Bluetooth, Wi-Fi, ZigBee, etc. are types of local connectivity used for house or office automation projects. GSM, 4G, 5G and RF are other types of connectivity used for long range communication. Some of the Bluetooth, GSM or RF modules are readily available in marketplace. The rest of the complex modules need to be built specifically depending on the application complexity.

A. Multi-Protocol Unit Designed for the IoT Platform

In general, each unit should carry out the following steps:

- Wait for and detect connected devices.
- Determine the device's accessory mode support.
- Attempt to start the device in accessory mode if needed.
- Establish communication with the device if it supports the Android accessory protocol.

1) ZigBee module: The ZigBee protocol was developed with low-cost, low-power consumption, two ways wireless communications standard. Solutions adopting ZigBee standard are embedded in consumer electronics, PC peripherals, and medical sensor applications.

2) Bluetooth module: The functional requirement for Bluetooth networking encapsulation protocol includes the following, support for common networking protocols such as IPv4, IPv6, IPX, and other existing or emerging network protocols as defined by the Network protocol types. Many protocols are used for various computing devices together. Although IPv4 and IPv6 are perceived as the most important networking protocols, it is a requirement that Bluetooth Networking is able to support other popular protocols Low Overhead.

3) Wi-Fi module: Wi-Fi is a new technology defined by the Wi-Fi Alliance aiming to enhance direct device to device communications.

Thus, given the wide base of devices with Wi-Fi capabilities, and the fact that it can be entirely implemented in software over traditional Wi-Fi radios; this technology is expected to have a significant impact.

To connect several sensors on the same platform using different protocols, one has to think about the conversion of the protocol. Then designing and developing an HTML interface for multi-protocol exchanger. The HTML interface (Fig. 3) showed the desire choice of exchange protocols:

- Wi-Fi to Bluetooth
- Ethernet to Bluetooth
- Ethernet to Wi-Fi
- ZigBee to Bluetooth
- ZigBee to Wi-Fi

Fig. 4 shows the data transfer between the HTML interface and the hardware part. Using an Arduino board coupled with several modules such as Wi-Fi, ZigBee, and Bluetooth. The Arduino board is programmed using C Language.

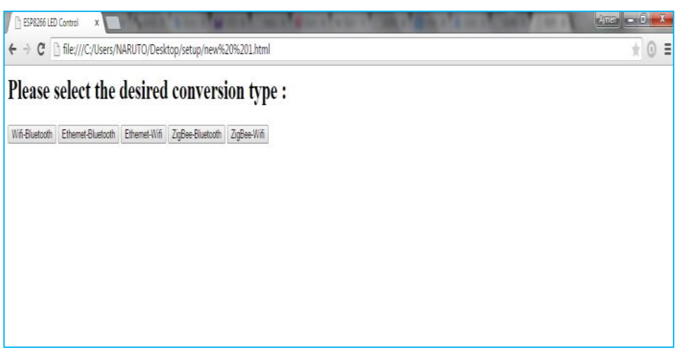

Fig. 3. HTML interface of specific multi-protocol unit for universal connectivity.

Fig. 4. Pulse and oxygen in blood sensor (SPO2).

V. WBSN for Monitoring Parameters of IOT Healthcare System

The IoT technology is a very important key in Wireless Body Sensor Network (WBSN) [29]. It connects a set of sensors into a network through wireless communication system. The sensor nodes are normally lightweight, inexpensive, easy to deploy and maintain, but the capability and functionality are limited by resources (sensors, processors, memories, energy sources, etc.) [30]. Specific multi-protocol unit, web and mobile applications, are emphasized in the design of our IoT platform for healthcare.

The sensors can be used for collecting and transmitting information about their surrounding environment using android interfaces and web.

The data is sent through Wi-Fi, ZigBee or Bluetooth independently of protocol used by the sensor.

Pulse oximetry a noninvasive method of indicating the arterial oxygen saturation of functional hemoglobin. Oxygen saturation is defined as the measurement of the amount of oxygen dissolved in blood, based on the detection of Hemoglobin and Deoxyhemoglobin. Two different light wavelengths are used to measure the actual difference in the absorption spectra of HbO2 and Hb. The bloodstream is affected by the concentration of HbO2 and Hb, and their absorption coefficients are measured using two wavelengths 660 nm (red light spectra) and 940 nm (infrared light spectra). Deoxygenated and oxygenated hemoglobin absorb different wavelengths. Fig. 5 shows the data transfer (Pulse=98cpm, Oxygen=88%, in blood) from sensor to the android interface.

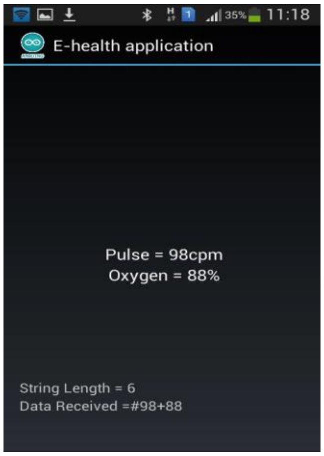

Fig. 5. Android interface: data receiving.

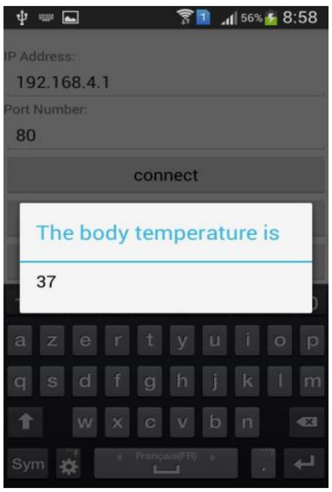

Fig. 6. Android interface: body temperature.

This sensor allows measuring the body temperature. It is of great medical importance to measure body temperature. The reason is that a number of diseases are accompanied by characteristic changes in body temperature. Likewise, the course of certain diseases can be monitored by measuring body temperature, and the efficiency of a treatment initiated can be evaluated by the physician. The transfer of the temperature, from body sensor to the android mobile interface is given in Fig. 6.

All data are transferred in real time to the doctor in two ways: a mobile or web interfaces.

VI. Android Interfaces

Android allows implementing device specifications and drivers. The hardware abstraction layer (HAL) provides a standard method for creating software hooks between the Android platform stack and hardware. The Android operating system is also an open source, to develop interfaces and enhancements. To ensure devices maintaining a high level of quality and offering a consistent user experience, each device must pass tests in the compatibility test suite (CTS). The CTS verifies devices to meet a quality standard that ensures running applications reliably. Users have easily a good experience for details on the CTS. Internet of Things based on Communication Technologies play a significant role in Healthcare systems and has contribution in development of medical information systems.

The development of IoT platforms using android applications ensures and increases the patient's safety and the quality of life and other healthcare activities. The tracking, tracing and monitoring of patients and healthcare actors activities are challenging research activities. The system advises and alerts via Android interface in real time 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.

In the experimental IoT platform, two main actors are used: patients and doctors.

A. Android Unit for Doctors

This section present some Android interfaces for doctors. Fig. 7 shows the registration and the doctor desk. The doctor can make a registration or unsubscribe freely.

For more account security of the doctors, each one should have a code (see Fig. 8).

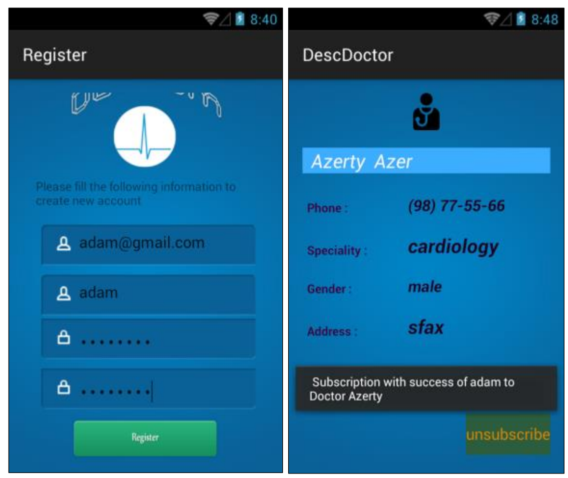

Fig. 7. Register and doctor desk access.

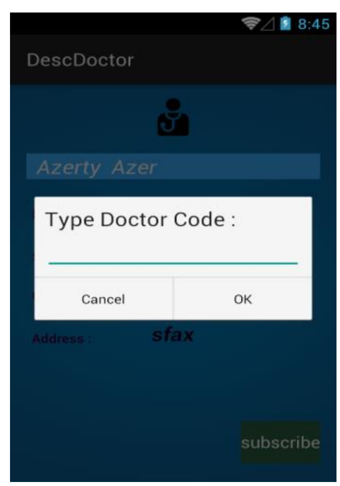

Fig. 8. Doctor typing a code.

B. Android Unit for Patient

For proper platform operations, it's necessary to develop some android interfaces, as mentioned in Fig. 9 to 12. In effect the patient can make a registration (Fig. 9) and after the authentication a window of the main menu opens (Fig. 10). The main menu contains several choices:

- View Profile: For updating profile.
- Doctors List: To see the list of doctors in the various services.
- New Exam: To receive the list of new exams given by his doctor.
- Medical Exams: History of analyzes and medical prescriptions.

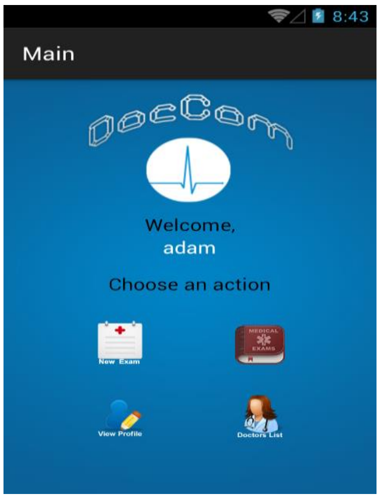

Fig. 9. Patient main menu.

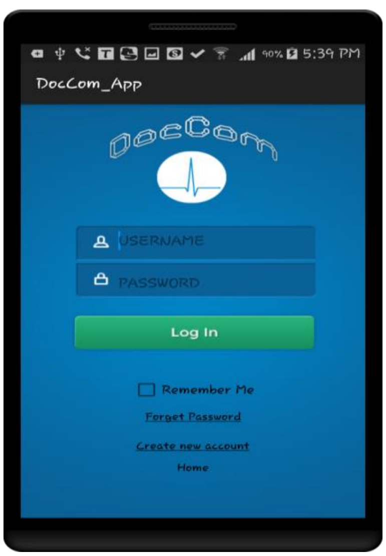

Fig. 10. Patient authentication.

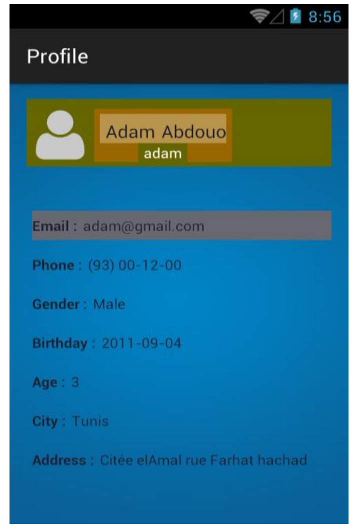

Fig. 11. Patient profile.

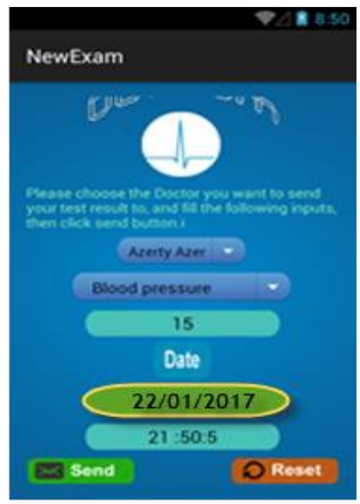

Fig. 12. Patient send medical test.

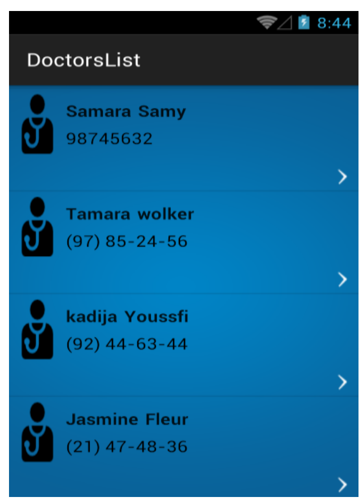

Fig. 13. Doctors list.

The patient can see his profile, choose his doctor and send medical test (Fig. 12 and 13).

VII. Static Aspect: Class Diagram

Class diagrams are UML diagrams used to model the entities (classes) involved in the system as well as the different relationships between them. The class diagram contains attributes, methods, and associations of objects. Indeed, an object is an identifiable entity that may have a physical existence (a person) or not have it (message). Each object has a set of attributes (object structure) and a set of methods (object behavior). A set of similar objects (having the same structure and behavior) forms a class of objects. Attributes and methods can then be defined in common at the class level. Obviously, classes in RAM are often linked to persistent data (stored in database, in files, in directories, etc.).

Based on the study of the existing system and the different use case diagrams, have been able to identify the main classes illustrated in Fig. 14 for a clearer view of the system under study. From this diagram, the entities of the corresponding database are cleared in the application to be developed.

VIII. Web Application

There are many communication protocols which can be used by the IoT healthcare to communicate with the web and mobile applications. Here discussion some of the popular technologies along with their pros and cons.

Plain HTTP: This is by far the most ubiquitous protocol. It's widely accepted by servers and being backed by Internet standards, has least compatibility issues. It also maps naturally with the RESTful APIs. However it suffers from large overhead in form of HTTP headers and text based format. It is stateless despite being run on top of TCP. That makes it unsuitable for real-time usage. The client must send a request in order to get a response (command) from the server. Client has to keep polling for updates from the server.

CoAP: Constrained Application Protocol can be considered to be binary version of HTTP. It improves on some limitations on HTTP. It has very concise headers and supported binary data format thus reducing the overhead. It can be used on top of TCP or other transport as well even SMS. CoAP packets can be easily translated to a HTTP packet. However because of negligible Internet infrastructure support it does not run well with firewalls, proxies and routers. Thus this protocol is only suitable for private networks typically inside the sensor network.

Web Sockets: It is a new protocol also backed by web standards. It has the same addressing and handshake mechanism as used by HTTP, thus making it compatible with existing network infrastructure. Once handshake is complete it switches to duplex communication on top of TCP. This makes it suitable for real time, two way communication. It's especially suited in shared hosting environments and gateways operating behind proxies.

MQTT: Is also a popular protocol running (optionally) on top of TCP. It has a topic subscriber model. Though more suited for broadcasting messages to interested gateways, it's also used for gateway to server communication. It has some features like last message persistence and will and testament message that make it useful for IoT application.

AMQP: This perhaps is the most suited protocol for gateway server communication. This protocol acts as a storing queue and ensures that packets are not lost, even in case of temporary outage.

XMPP: Extensible Messaging and Presence Protocol is a popular protocol used by chat clients for real time communication. It standardizes lot of things like user authentication and message IDs. However owing to its complex specification and exchange of data using verbose XML format makes it suitable for IoT applications.

Here the flexible design for sensor data monitoring and control is presented. The application is a generic one without special requirements for security or reliability. The goal of this application is to replace a traditional and manual system with an intelligent computing solution that allows physicians to manage patients and their medical records by replacing conventional medical records on paper with computerized medical records and on the other hand allowing patients to follow their doctors and update them about their state of health (Fig. 12).

The web Application called DocCom offers security for every doctor, in fact everyone must make a registration in his domain of specialty (see Fig. 15).

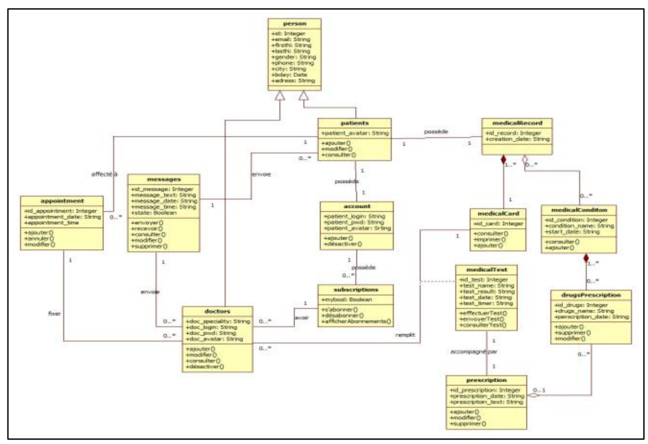

Fig. 14. General class diagram.

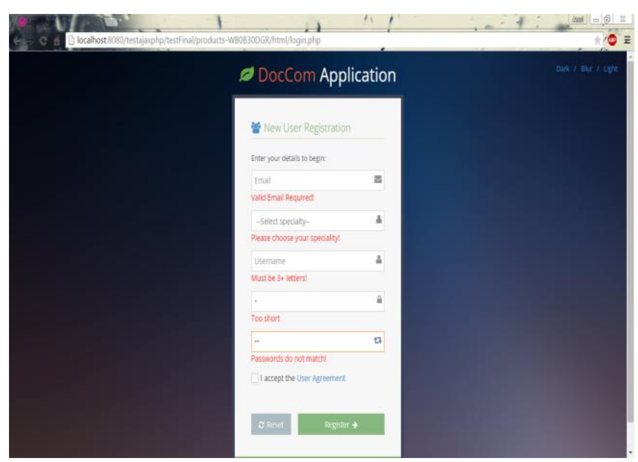

Fig. 15. Registration interface.

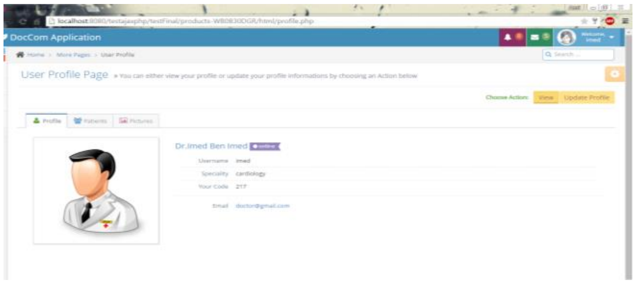

Fig. 16. Medical consultation interface.

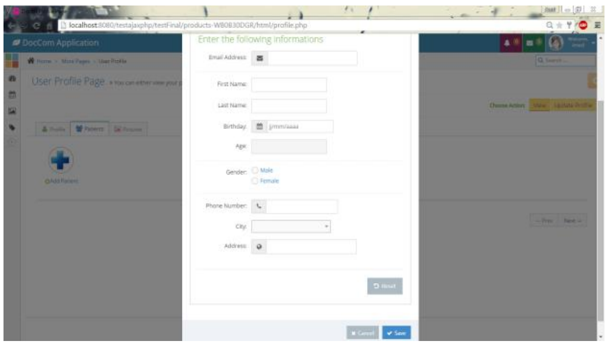

Fig. 17. Adding new patient.

As you can see in DocCom application (Fig. 16) the Doctor profile contains the following headings:

- User name,
- Specialty,
- Security code.

Doctor can either view profile or update profile information by choosing an action. At the top right of the interface you can see two icon the first for notification and alert in real time and the second for emails.

The doctor can add a new patient by entering the following information (Fig. 17):

- Email address,
- First name,
- Last name,
- Birthday,
- Gender,
- Phone number,
- City and Address.

Patient management is done using the notification as shown in Fig. 18. The doctor can directly see the notification of each patient and respond. By mail the doctor can receive medical analysis tests sent by the patient or by the laboratory of medical analysis. The doctor may send a medical prescription or a medical analysis test for each patient. In case of emergency the doctor can send an alert to a nearest medical center.

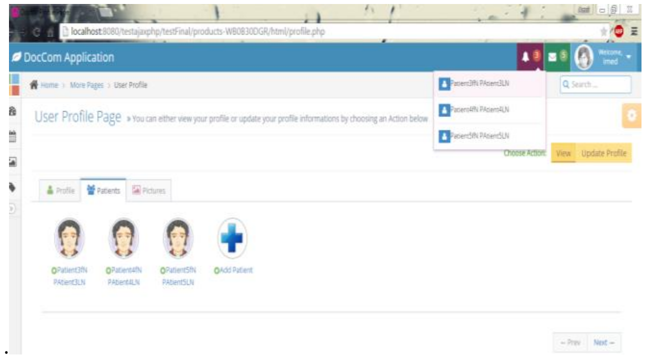

Fig. 18. List of patients registered for this doctor.

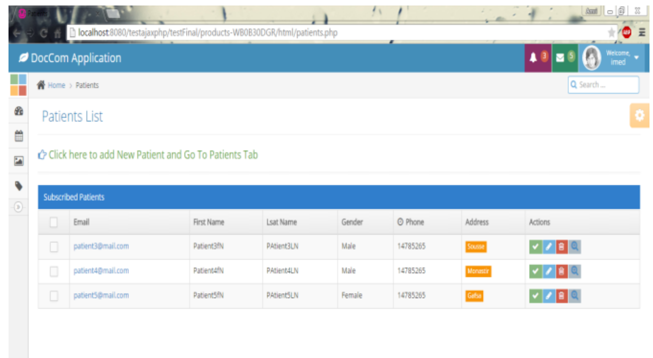

Fig. 19. Patients management for doctor.

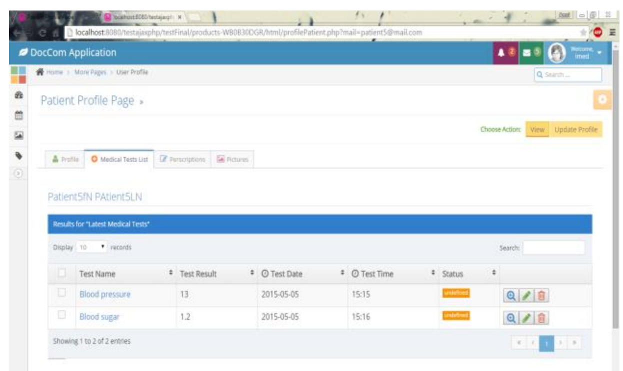

Fig. 20. Medical consultation management: medical tests sent by the patient.

The above interface shows the list of patients for each doctor, of course he may do the necessary acts for each patient. The doctor can see the historical of medical tests and historical of medical prescriptions for each patient.

DocCom (Fig. 15 to 20) is the web application developed to meet patients' and doctors' needs, analytical laboratories and hospitals. Each user can create an account, the patient send medical analysis to the doctor via DocCom mobile application, the doctor answers by a medical prescription or by an appointment at the hospital. In the critical case of a patient, his doctor receives an alert on his smart phone and on the web application DocCom, so the doctor can do the necessary actions.

IX. Conclusions

The smart IoT for healthcare system has been designed. It aims to help patients to consult anywhere doctors, and doctors to follow up patient's requests and data. It uses Wireless Body Sensor and information technologies to provide remotely clinical healthcare. It helps to reduce distance barriers and improve access to medical services. It is also used to save lives in critical care and emergency situations inside cities and rural communities.

A mobile application allows:

- The patient to connect via IoT platform.
- Sensing the health parameters.
- Contacting the doctor.
- Sending in real time and easily the results of performed medical tests.
- Following the medical record.

The physician doctor manages patient's consultations and remote follow-up.

Today's 4G and 5G networks use the latest technologies and continue to offer faster data access. The mobile Internet inspires researchers to meet faster data transmission with greater capacity.

Mobile healthcare application concepts have been developed over many years and some have become widely used. It is very important for doctors and patients to be in touch in real time through the same cloud plate form. Healthcare can be improved when reducing time of communication and diagnosis.

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