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Prevention of Pressure Ulcers and Incontinence-Associated Dermatitis in Home Hospitalization of Older Adults

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Abstract

Background/Objectives: Older adults in home hospitalization are prone to health complications due to factors that may hinder recovery. Many of these are a result of inadequate care, as is the case with afflictions such as skin ulcers and incontinence-associated dermatitis. The problem is even more evident when the older adult cannot take care of him/herself and needs a person who is permanently monitoring their health. Situations such as those mentioned above affect the quality of life of patients and caregivers causing discomfort, additional health problems and an increase in medical costs to treat the new conditions. The main objective of the present work is to show an architecture that allows to remotely monitoring conditions that can improve the health of the elderly in home hospitalization. **Methods:** The methodology used in the construction of the architectural model is Rational Unified Process and the diagrams used in the description of the architecture are based on Unified Modeling Language, which is considered a standard in software development. **Findings:** The present work provides a solution to the problem identified through the proposal of architecture to remotely monitor the elderly in hospital care, supported by the Internet of Things. This document presents a case study that checks the validity of the functionality of the architecture. **Novelty:** In the context of the related work the results presented in the document are novel because they contribute to a solution that allows to monitor health conditions of elderly patients who leave the hospitals and must continue their recovery at home, especially older adults cannot care for themselves during recovery and whose care must be permanent to avoid later complications.

Keywords: Architecture, Dermatitis, Internet of Things, Pressure Ulcers, Remote Monitoring, Wearable Sensors

1. Introduction

Healthcare is a priority at any stage of life. The changes that occur to people make them susceptible to health problems and subsequently some level of dependence. This is the reason why older adults or the elderly may need hospitalization at home at some point in their lives[1,2].

It is common that when an older adult is treated in a hospital, he/she is referred or discharged to homecare[3,4]. This is done so that environmental conditions are conducive to recovery. In some cases, it is more convenient to carry out home care.

It is important to have timely and permanent care of the elderly since neglect could significantly affect their quality of life and cause problems to arise due to the inability to treat pre-existing conditions in a timely manner. A few examples are: localized lesions on the skin or underlying tissue called pressure ulcers[5,6], which are diseases caused as a result of prolonged pressure on the same part of the body. People in a state of incapacity are disproportionately exposed to pressure ulcers. Pressure ulcers result from a person remaining in the same position for a long time.

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Another example is incontinence-associated dermatitis[7-9], which also corresponds to a skin lesion, as a sequel of fecal and/or urinary incontinence. One of the main causes of this disease is that people do not change diapers or absorbent garments that are used to sanitize and avoid contamination frequently enough.

The quality of life of relatives, friends or caregivers of the elderly can also be affected by the problems mentioned above. They worry about not having a reliable way to care and intervene promptly in case of an emergency. In addition to this concern, additional costs can be generated as a result of these problems.

When an older adult or elderly is in home care, it is important to keep him/her permanently monitored and assess the progress of recovery. When an older adult cannot take care of him/herself during recovery, he/she is exposed to subsequent complications such as those mentioned above, which in turn can lead to more visits to the doctor and increase of the cost of the medication and treatments. This is where technology can play an important role in finding solutions to several health problems for the elderly[10].

There are initiatives that propose solutions to the problems of monitoring factors that affect the health of the elderly. Technology provides important solutions in this field.

H3IoT[11] is architecture for a home health center using the Internet of Things for Health Supervision of the elderly. Thanks to this architecture, the health of the elderly who are at home can be easily monitored by their families, doctors, nearby hospitals and caregivers who are in distant places. In addition to the information stored in the cloud, it could be analyzed for the detailed medical history of the elderly person.

Despite this, H3IoT does not currently provide support for emergency medical care for critically ill seniors. This means that it is necessary to add functionalities for home hospitalization of adults who cannot fend for themselves.

There is an initiative that defines an architecture based on IoT to offer medical environments for older adults[12]. It is a layered architecture or diagram looking for ways to automate homes, provide security, control and communication. This allows for flexibility and scalability.

Although there are many advantages, the whole system is installed in one place, which can become a disadvantage for the system if the older adult being monitored is moved to another place. The whole system must be moved and installed where the elderly live. This can cause additional costs since the sensors and other elements used for monitoring are added to the physical facilities of the places in which the monitoring is being carried out.

There is an initiative that proposes a Mobile Application for Ambulatory Electrocardiographic Monitoring in Clinics and Domestic Environments[13]. The solution is designed for IOS and Android operating systems. It is composed of buttons, switches, sliders and rotating screens that run in two settings: patient mode and doctor mode, allowing the medical staff to define different configurations. Both modes allow users to view real-time readings and captured information. The solution is very useful; however, it has been designed for patients in general without considering its user-friendliness to the elderly, especially when they are in a state of dependence at home.

Can be identifiedan initiative that proposes a design and production of an integrated system of patients with cardiac arrhythmias[14]. The system is based on a wireless sensor network and can be used in hospitals or at home. Although the solution is important, it has not yet been determined whether it can be scalable to other types of measurements that can affect the elderly when hospitalized.

There is another initiative that presents the problem of security of mobile devices connected to wireless networks that are used in speech therapies[15]. The objective is to maintain the confidentiality of the patient's personal data and also to avoid interference when communicating simultaneously with the control center. The work is of great importance and can be useful in remote monitoring systems for older adults. However, it must be adapted so that it can incorporate diverse sensors that allow you to control conditions that can affect the health of the patients.

Despite the solutions presented above, which are useful, it is still difficult to find an economical and useful solution that allows telemonitoring conditions that may improve the health of the elderly in hospitalization, especially when they cannot care for themselves.

In the context of the related work the results presented in the document are novel because they contribute to a solution that allows the monitoring of the health conditions of elderly patients who leave hospital and must continue their recovery at home, especially older adults that cannot care for themselves during recovery and

whose care must be permanent to avoid later complications.

Also new is the manufacture of a wearable that incorporates free hardware and commercial availability sensors, which allows a low-cost solution that enables the patient to be mobilized and to which new sensors could easily be added that evaluate different health conditions of the elderly in hospital care.

The main objective of the present work is to show an architecture that allows the remote monitoring of conditions that can improve the health of the elderly in home hospitalization. The work contains: the method used, the description of the architecture proposed, a case study of the effects of humidity and prostration on dermatitis or skin ulcers by pressure, and finally the conclusions.

2. Materials and Methods

This work is supported in a descriptive methodology to distinguish and identify many aspects, dimensions and components of the phenomenon in search.

The methodology used in the construction of the architectural model is RUP - Rational Unified Process[16]. This methodology was used because it focuses on architecture which easily helps to connect and integrate processes, methods, techniques and notations in software engineering.

The diagrams used in the description of the architecture are based on UML[18] a modeling language which is considered a standard in software development.

A "wearable" for the older adult patient was designed along with a humidity sensor and a pressure sensor. They use the sensors (FSR sensors) for data capture. An Esp 8266 module is used for the Internet connection and a multiplexer for connecting multiple force sensors.

The messaging service Google Cloud Messaging[18] has been used to send messages to mobile devices.

A controller Arduino[19], has been used to receive signals from the sensors and send notifications to the patient's caregiver.

The development of the architecture follows the IEEE P2413 standard, which presents guidelines that follow systems based on the Internet of Things[20,21].

3. Results and Discussion

Table 1. Functional system requirements

Code	Requirement
REF01	Sensing Status of older adult Patient
REF02	Receiving patient Sensing Notifications
REF03	Viewing Patient Information
REF04	Managing medical notifications and Medication
REF05	Receiving Medical Appointments and Medication Notifications
REF06	Managing the Platform

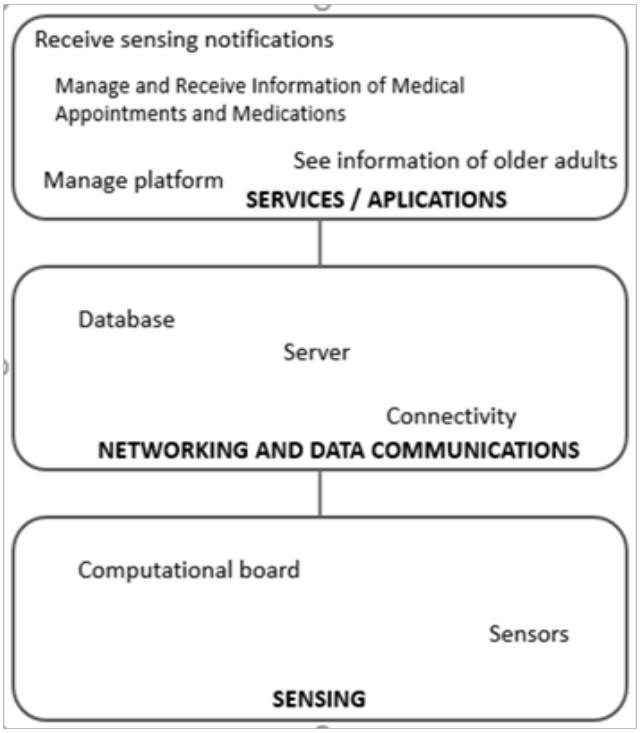

Figure 1. Attention on the requirements in Levels of an IOT Architecture.

In order to identify the system requirements, the following criteria have been considered:

- Risk situations and time availability in the care of the elderly: this item includes the level of health risk to which older adults are exposed, the time and availability of caregivers.
- Technological resources: this item includes the technological resources that are currently available to the caregivers, necessary to implement the telemonitoring system.

- Ways to care for the elderly: this item evaluates how the caregivers perform the care of the elderly at home and the level of satisfaction regarding that care.
- Tools for care of the elderly: This item includes the level of need from the respondents to implement a reliable method that allows them to stay informed about the health of the elderly and perform constant monitoring and care.

After assessing the care of several elderly patients with home care, the following requirements have been identified (Table 1).

3.1. System Architecture

IEEE p2413[20] defines three basic levels that a system based on IOT should implement (Figure 1). Accordingly, each of the requirements of the systems is met with the IOT levels, as follows:

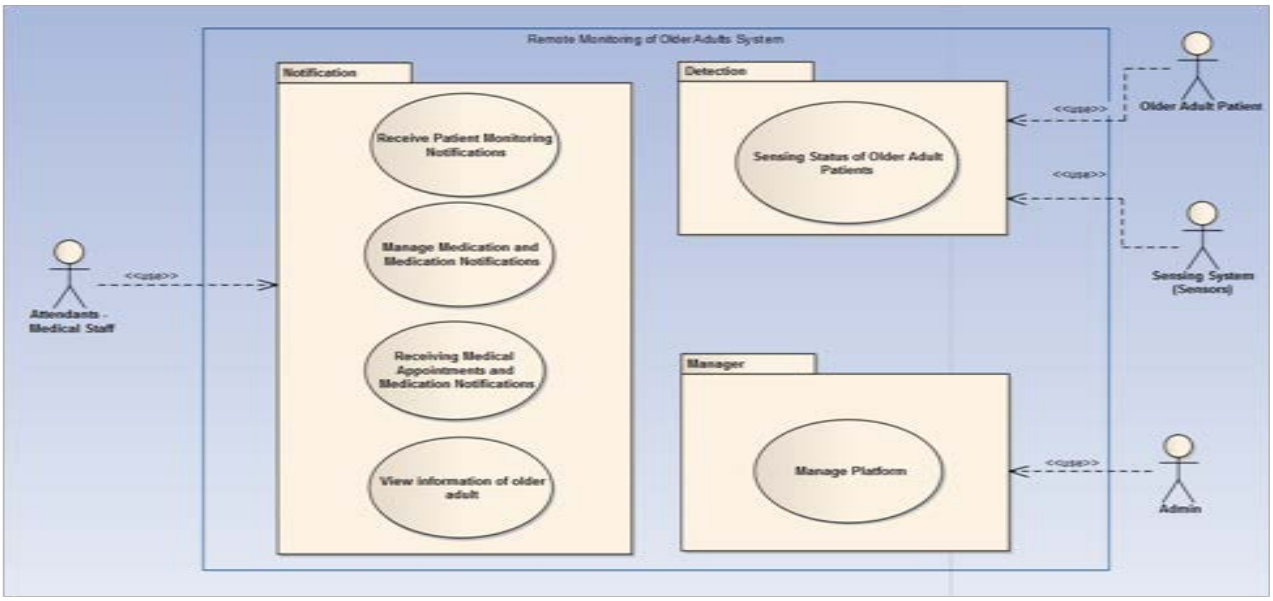

Figure 2. **View Scenarios**

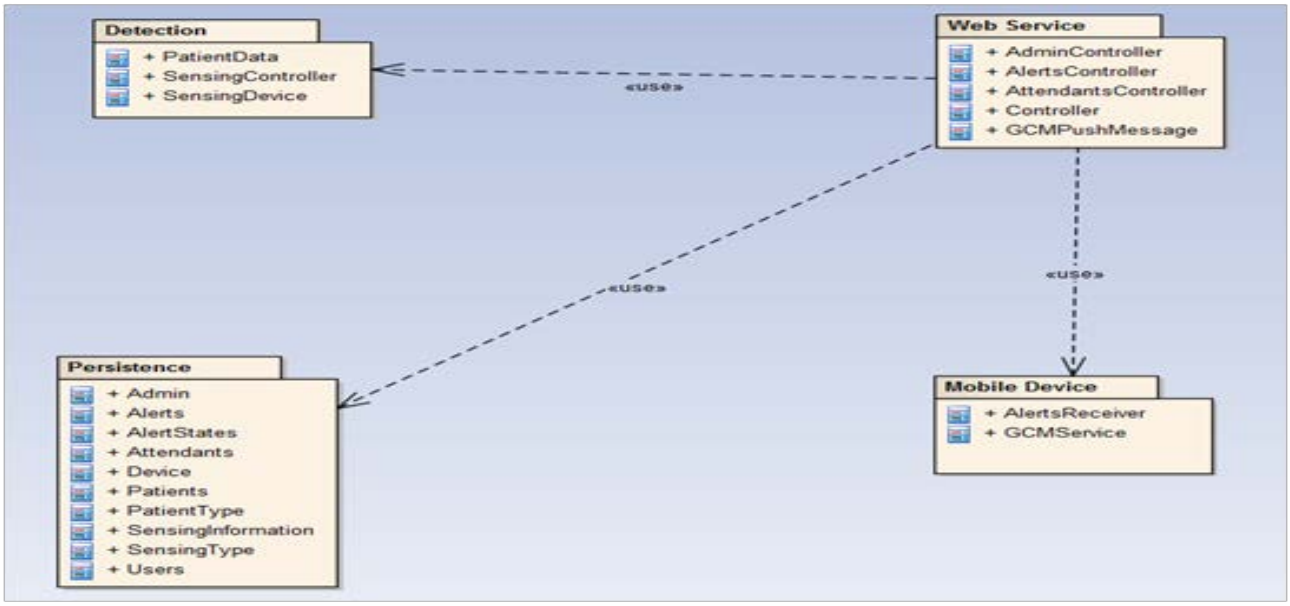

Figure 3. **Development view.**

In the next view of the architecture (Figure 2), the users of the system are identified; this view represents user perceptions of the system's functionalities and their interaction according to the fulfillment of the requirements.

The Development view (Figure 3) illustrates the system from the perspective of the developer, which is focused on the management of the software utilized. This view is focused on the actual organization of software modules in the development environment. It is illustrated by packages with close and well-defined relationships between them.

The main function of the ***Detection*** packet is to capture patient data; this capture is carried out through the ***SensingDeviceclass***. Later this data is sent to the ***Web Service package***. In this package, the ***AttendantsController*** receives the data and performs a validation in order to determine if it is necessary to send an alert. If an alert is required, the ***GCM Push Messageclass*** sends the data with the information that will be shown to the Medical Personnel, notifying them of the event that has occurred with the older adult. The ***GCM Serviceclass*** of the ***Mobile Device package*** receives this data and it is responsible for generating the notification on the mobile device so that it can be seen by the users.

In addition to generating sensing notifications to the elderly, the ***Mobile Device package*** provides reminders of medical appointments and when it is time to take medicines. This is possible through the ***AlertsReceiver class***.

The main processes performed by the system are as follows:

1. Monitoring the older adult/elderly: this process starts when the older adult/elderly wears the garment that contains the sensors which monitor the patient's data. Then the data is analyzed with the purpose of determining if it is necessary to send an alert to the mobile device of the caregiver - Medical Personnel; The alert will be sent if the data received is outside the normal ranges previously defined; In case the data is within the normal range, it will simply be saved for the purpose of storing historical records of this information.
2. Managing medical appointments or medications: Older adults/elderly often need to be attended at medical centers so their health status can be analyzed by professionals specialized in medicine. Prescription medications should be taken at different times of the day and with proper control to produce the results expected by doctors. Taking into account this situation, the activity described here is carried out, which begins with the reminder of a medical appointment or for taking a medication. When creating or modifying these reminders, the platform Mobile will enter a constant validation to determine if the scheduled time in the reminder management matches the current time of the device. If the hours match, a message will immediately show to the medical personnel via the mobile device informing them that the time is approaching for the medical appointment of the older adult, or informing them when to take a medication.

In the physical view (Figure 4) the relationship between the hardware and the software of the tele-monitoring architecture supported by IOT is detailed, representing it through the distribution of components within the work teams.

Figure 4 shows the main layers of the solution based on IOT; Such as ***FSR Sensors, Sensing, Web Server, Google Server, And Android Mobile App***. Next, each of the components that are part of the above-mentioned layers is defined:

1. FSR Sensors: In this layer, the sensors are located. Its function is to obtain data from the older adult/elder for further analysis or storage.
   Figure 5 shows part of the implementation of FSR Sensor component functionality that retrieves sensor data and processes it:
2. Sensing: The data obtained in the layer described above is received by an Arduino plate; through this plate the data is sent to the Web Server (Figure 6) for analysis and storage.
3. Web Server: In this layer, there are three components. The first one is in charge of the management of the platform and called ***Platform Manager***, the second is the component responsible for data persistence called ***Data Base*** and the third is in charge of receiving and storing alert data that comes from the ***Sensing layer***, and sending it to the Google Server layer; this component is called ***Alerts Manager***.
4. Google Server: In this layer, the component called ***Google Cloud Messaging*** is located, through which the communication with the mobile device is made to receive the data that will be displayed in the notifications of the mobile application.

Figure 7 shows part of the implementation of ***Alerts Manager*** component functionality that uses the ***Google Cloud Messaging*** service to send alerts to users when risk factors are detected.

5. Mobile Device: In this layer, there are four components responsible for generating notifications of the alerts of the older adult's sensors through the ***Sensing Notifications component***; managing appointment reminders and medications and generating the respective notifications through the ***Medical Appointment Reminder*** and ***Medication Reminder components***; and also displaying the historical information of the generated alerts to the older adult through the ***Alerts Manager component***.

a. Case Study: Remote Control of Pressure Ulcers and Incontinence-Associated Dermatitis of an Old Adult in Home Hospitalization

The patient has the following characteristics: an older adult, 81-year-old female, suffers from Diabetes. Because of this disease, one of her legs was amputated. For this reason, the patient must remain in the same position for a long time in her wheelchair. This is described in this document as State of Prostration. Because of her advanced age the patient has increasing difficulty performing basic activities on her own. Taking into account the condition of the patient, monitoring and constant care are necessary.

The patient needs attention in all basic care such as food, grooming, taking medication, medical examination visits and periodic changes in position to avoid skin diseases due to pressure on the same area for an extended time.

Traditionally, the patient is treated as follows: since the caregiver does not have the availability required for the care of his relative, a professional career is hired to care for the patient. This professional career works from 9:00 a.m. until 5:30 p.m.

At night, the responsibility for patient care are the family member(s) who must constantly change the patient's position and place a diaper since the patient can't get up. The family must also administer medicines.

The caregiver receives by e-mail a file necessary for the installation of this device and the software that receives the information of the sensors.

When installing the mobile application on the device the caregiver can immediately receive alerts from pressure and humidity monitoring (Figure 8). In addition to

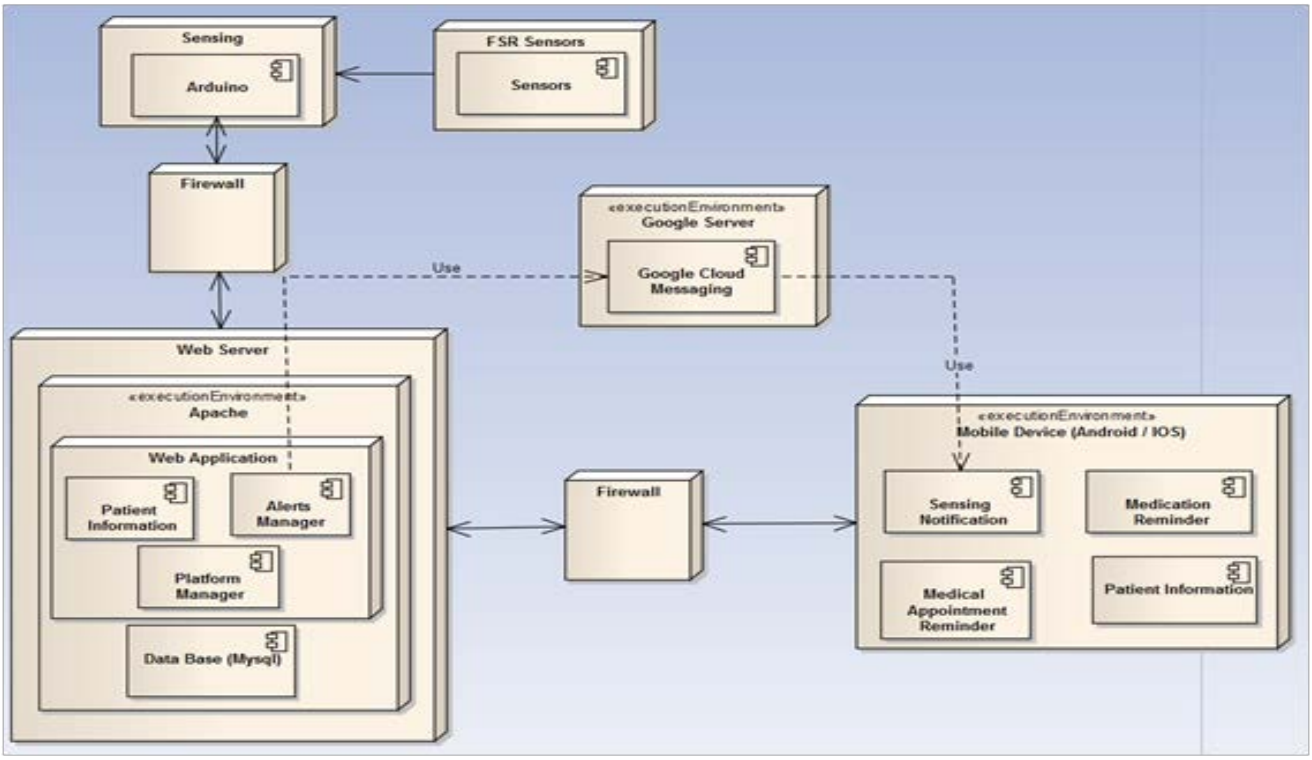

Figure 4. Physical View of Architecture.

alerts through the mobile application, it is possible to create reminders of medical appointments and medications.

```
// get sensor value and process
void checkPosition() {
  uint16 value = FSR.getValue();
  Serial.println("Checking Position" + String(value));
  if (maxRange != previusMaxRange || minRange != previusMinRange) {
    if (value - MAX_ANALOG_OSCILATION < 0) {
      minRange = 0;
      previusMinRange = minRange;
      maxRange = value + MAX_ANALOG_OSCILATION;
      previusMaxRange = value + MAX_ANALOG_OSCILATION;
    } else if (value + MAX_ANALOG_OSCILATION > 1023) {
      maxRange = 1023;
      previusMaxRange = maxRange;
      minRange = value - MAX_ANALOG_OSCILATION;
      previusMinRange = value - MAX_ANALOG_OSCILATION;
    } else {
      maxRange = value + MAX_ANALOG_OSCILATION;
      previusMaxRange = value + MAX_ANALOG_OSCILATION;
      minRange = value - MAX_ANALOG_OSCILATION;
      previusMinRange = value - MAX_ANALOG_OSCILATION;
    }
  }
  if (value < minRange || value > maxRange) {
    previusMaxRange++;
    previusMinRange++;
    previusPositiontime = millis();
#ifdef DEBUGGIN
    Serial.println("The patient has moved..");
#endif
  }
```

Figure 5. Sensor data retrieval and processing.

```
// Send Data
void sendData() {
  RestClient *restclient = new RestClient("monitor.grupoesoluciones.com");
  String payload = "";
  payload.concat("/controlador/ReceptorDatosPaciente.php?");
  payload.concat("&cantidad=1");
  payload.concat("&estado_parametro_sensado1=" +
                 String(estado_parametro_sensado1));
  payload.concat("&id_tipo_sensado1=2");
  if (FSR.getValue() < 10) {
    payload.concat("&parametro_sensado1=10");
  } else {
    payload.concat("&parametro_sensado1=" + String(FSR.getValue()));
  }
  payload.concat("&identificacion_paciente=" + String(identificacion));

  Serial.println(payload);

  restclient->get(payload.c_str());
#ifdef DEBUGGIN
  Serial.println("Data sent..!!");
#endif
}
```

Figure 6. Send data to the Web Server.

```
public static function sendAlerts($idPaciente, $mensaje, $nombrePaciente,
            $parametrosNormales, $parametroSensado, $idTipoSensado,
            $tipoSensado){
        $tokens = ControladorInformacionAlertas::obtenerTokens($idPaciente);
        $arraytokens = json_decode($tokens);
        $device = array();
        foreach ($arraytokens as $posicion) {
            array_push($device, $posicion->token);
        }
        //Se extrae la fecha y hora en espaniol y de bogota
        setlocale(LC_TIME, 'spanish');
        date_default_timezone_set('America/Bogota');
        $fecha = strftime("%#Y-%m-%d");
        $hora = date("H:i:s");
        $apiKey = "AIzaSyA1BmJmOYPcsMIIKm7iuqL6vWu8mZSnLSU";

        $gcpm = new GCMPushMessage($apiKey);
        $gcpm->setDevices($device);
        $respuesta = $gcpm->send($idPaciente, $idTipoSensado, $mensaje,
                    $nombrePaciente, $parametrosNormales, $parametroSensado,
                    $tipoSensado, $fecha, $hora,
                    array('title' => 'Test title'));
        AlertsManager::crear($mensaje, $hora, $fecha, $parametroSensado,
                    $idPaciente, $idTipoSensado);

}
```

Figure 7. Algorithm to sends Alerts.

The monitoring system is connected to the Internet via WIFI to send notifications (Figure 8).

An ergonomic garment is used which has been designed so that the circuits and components will be easily installed and keep the pressure sensor force in a fixed place and located in the proper place to be pressed by the patient (Figure 9).

When the patient is in her wheelchair, she will put pressure on the sensor (Figure 10). The sensing system is programmed to record the duration for which the sensor remains pressed, if this duration is long enough an alert will be sent to the server, which will be in charge of configuring the notification that is sent to the mobile device.

The data sent by the sensing system is received by a web server. The analysis and verification of the patient's data is performed on the server. This analysis consists of checking if the data coming from the Arduino plate and corresponding to the older adult is within the normal parameters; if so, it is stored in a MySQL database in which the information of patients, caregivers and alerts are also stored.

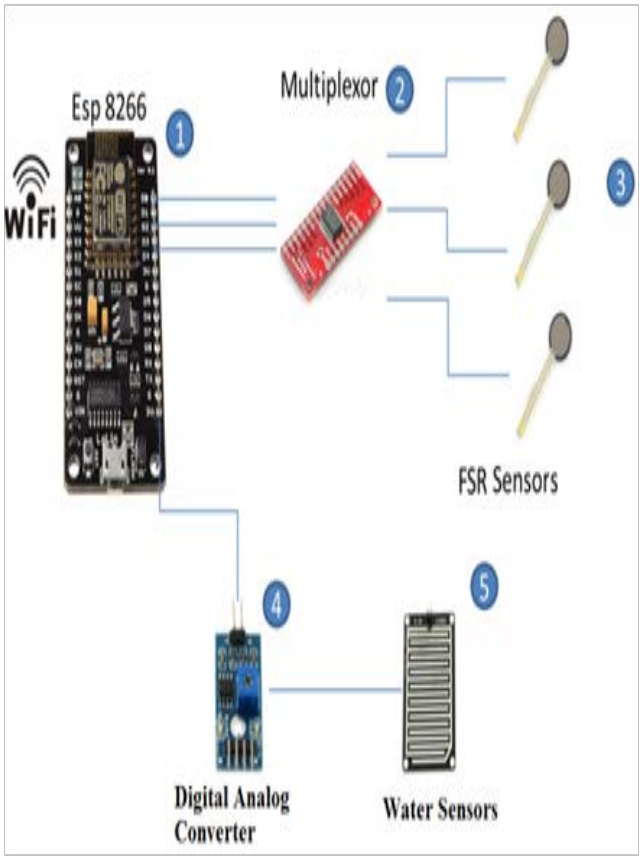

Figure 8. Remote Monitoring System.

Figure 9. Wearable with Sensing System.

Figure 10. Patient using Sensing System.

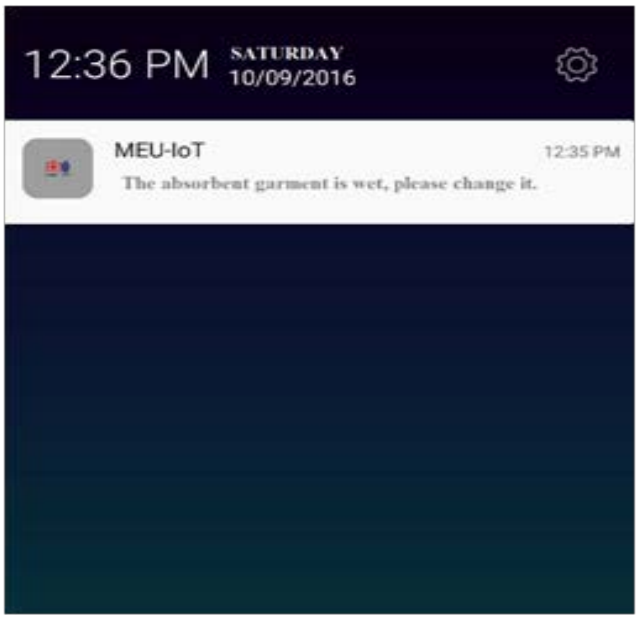

Figure 11. Notification of alert on mobile phone of the attendant.

If the data is not within the normal parameters, the system immediately generates the necessary information to send an alert message that will also be stored in the database. The information generated by the server after being stored in the database will be sent to the mobile device of the caregiver.

Taking into account that Android has been the mobile platform selected for this case study, a messaging service in the Google Cloud called ***Google Cloud Messaging(GCM)*** is used which requires a unique code

corresponding to each device to which you want to send a notification message. The code is registered in the database when accessing the system from the mobile device so that it can be used whenever it is necessary to send an alert to the device. ***GCM***, checks that the information provided by the server is correct and proceeds to send the message.

The alert message sent by ***GCM*** is received by a mobile device and shows the caregiver or medical personnel an alert message (Figure 11), allowing them to be informed and be able to intervene in case of one of the situations for which the monitoring is being carried out.

The ***FSR SENSOR*** component allows the capture of signals from multiple pressure sensors. This component may allow scaling of the system with the addition of sensors that can measure different health conditions. This allows the proposed architecture the opportunity to generate alerts by correlating health conditions. For example, it is possible for a temperature sensor to indicate normal ranges, but when checked in conjunction with pressure and humidity sensors may indicate a risk of possible complications for the patient due to the development of skin ulcers, and early warnings should be generated.

When monitoring for different conditions, as is necessary to ensure adequate control of the health of the patient, it is possible that each one of the conditions monitored require multiple sensors that generate a large number of signals, which must be evaluated by ***Web Server Layer***, before notification of the appropriate alerts. Due to the above, we are currently working on solving optimization problems and on the quality of attribute selection necessary to guarantee the efficiency and stability of the system.

4. Conclusions

The current work shows architecture of a tele-monitoring system for home hospitalization for older adults/elderly supported by Internet of Things (IOT) technologies. It is a work of importance that benefits families and older adults who are in this type of situation. Using new technologies such as IOT healthcare, risks are greatly reduced and timely, permanent care is possible.

The architecture proposed was tested through a real case study and proved robust and scalable allowing monitoring actions through various mobile devices. It allows the management of information of patients, caregivers, alerts and types of sensing using the web platform, offering the possibility of using various mobile technologies thanks to the architecture and fact that the design of the device has components with low coupling and high cohesion.

For this case study, the preliminary test results verified the good operation of the system in a real environment, without any interruption of the service and confirmed the ease of use of the administration components and the mobile application.

During the test of architecture and system components, an efficient behavior was observed in its Web, Mobile and Sensing components. All services were available during the trial period and complications or impediments to the proper functioning of the system were few. An excellent experience was achieved for the users who participated.

A total of 11 alerts were generated during the last 5 days of operation, which helped to prevent skin diseases in the patient due to prolonged skin pressure.

Thanks to the development of the case study, it can be concluded that the architecture proposed for the telemonitoring system for home hospitalization of elderly people supported by Internet of Things (IOT) Technologies, is a viable, efficient and accessible solution that answers the following question: How to improve the quality of life and reduce risk situations that may occur with elderly who are in home hospitalization, enabling timely care on a permanent basis? As it presents a viable, safe and inexpensive way to monitor older adults who are in home hospitalization, notifying their relatives and medical staff through timely alerts generated on their mobile devices in an immediate and reliable manner, and also centralizing in the same application care solutions such as reminders of medical appointments and medications.

In the near future, we plan to strengthen the present work by incorporating multiple sensors to measure a larger number of conditions that may affect the health of the elderly in home hospitalization, for example: pressure, temperature, heart rate, sweating, etc. The above implies undertaking initiatives of optimization of the algorithms, in order to guarantee the stability of the system. There are useful optimization initiatives to accomplish this and prevent excessive loading, a critical measure to avoid overheating hardware that can lead to faults and system instability when monitoring patients.

5. Acknowledgements

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