International Journal of Computing and Digital Systems
ISSN (2210-142X)
Int. J. Com. Dig. Sys. 8, No.1 (Jan-2019)
http://dx.doi.org/10.12785/ijcds/080102

Thingspeak Cloud Computing Platform Based ECG Diagnose System

Auday A.H. Mohamad[1], Noor Kareem Jumaa[1] and Sameer Hameed Majeed[1]

[1] *Computer Technology Eng. Dept., Al-Mansour University College, Baghdad, Iraq*

Received 4 Sep. 2018, Revised 16 Oct. 2018, Accepted 10 Nov. 2018, Published 1 Jan. 2019

Abstract: The Internet of Things (IoT) is a community of smart things that is a combination of sensors with network technology, cloud computing, and many data concepts. Presently, the IoT is applied in many fields, and one of the most critical issues is health monitoring systems since statistical analyses have shown that a human lose their life every minute across the globe. In Iraq, many lives are affected by heart attacks every day, because patients do not receive proper help at the right time. The electrocardiogram (ECG) signal is an important parameter for monitoring heart activity. This article focuses on the recruitment of IoT technology in the field of health applications and its main objective is to provide an ECG diagnostic system using Thingspeak IoT platform capability analysis and a reliable healthcare analytic system for patients that can be used by healthcare professionals for patient monitoring. The monitoring system is based on analysis and comparison of ECG signals using Principal Component Analysis (PCA).The proposed system collects and sends ECG signals from patients to the Thingspeak IoT platform for PCA. The system can classify the heart malady and gives people with unstable health a chance to be treated by healthcare professionals.

Keywords: ECG, IoT, Cloud Service, Thingspeak, Principal Component Analysis.

1. Introduction

Heart attacks and cardiovascular diseases are some of the main causes of death in many countries, and account for over 15 million deaths globally [1]. The delay between the first indication of any cardiac infirmity and the call for medical aid varies greatly between different patients and can have deadly consequences. From epidemiology data, we can conclude that the deployment of resources for early detection and treatment of heart disease has a higher potential of reducing fatality associated with cardiac disease than improved care after hospitalization. Therefore new strategies are needed to reduce the time before treatment [1, 2].

The Internet of Things (IoT) has no universal definition; instead, different definitions are used by different foundations and parties. The International Telecommunication Union (ITU) published an overview of the IoT in 2012 and defined the IoT as a society of global information infrastructure that enabled interconnected things to communicate with each other and achieve advanced services based on existing and evolving interoperable information and communication technologies [3]. Simply, the IoT is defined as a network of things connected to the Internet (Fig. 1 illustrates the components of an IoT system). In the IoT infrastructure, things are embedded with sensors to sense the environment, electronics for different functionalities, such as connectivity, and software for integrity purposes. In IoT systems, the environment is monitored by sensors, and data are transferred to the cloud through Internet connectivity [3, 4].

An efficient healthcare system should provide people with good healthcare services at any time and from anywhere in an economical and user-friendly manner. Currently, the healthcare system is undergoing a cultural shift from a traditional approach to a modernized, patient centered approach. In the traditional approach, healthcare professionals play the major role; they need to visit patients for necessary analysis and advising.

This approach has two basic problems. First, the healthcare professionals must be on site with the patient at all times. Second, the patient remains assumptive in a hospital and wired to bedside biomedical tools for a period. The IoT could solve these problems [2, 5].

An electrocardiogram (ECG) is a test that is used to determine the regular rhythmic activity of the heart condition. The electrocardiogram (ECG) signal illustrates

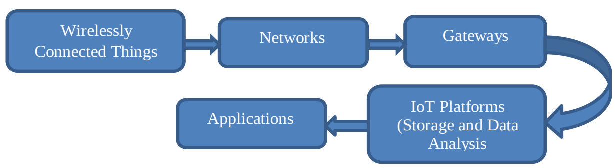

Figure 1. Components of an IoT systems.

E-mail:auday.mohamad@ieee.org, noor.jumaa@muc.edu.iq, samer.majeed@muc.edu.iq

the heart activity for a physician using electrical signals generated throughout the cardiac cycle; and measured using external electrodes. The medical importance of the ECG in cardiology is well established. ECGs are used to investigate abnormal heart rhythms and to determine heart rates and causes of chest pain. ECG heart activity is recorded on graph sheets or monitors by placing electrodes on a person's body. The records show a series of electrical waves that occur during each beat of the heart. The recorded waves have peaks and valleys, and are normally represented by the letters P, Q, R, S, T, and U (shown in Fig. 2). The U wave is not consistent and can be invisible in 70% of people. Clinically, the U wave is as important as the other waves [6, 7]. Fig. 3 shows different ECG samples for different heart beat cases.

In this article, an IoT health monitoring system is proposed and designed based on principal component analysis (PCA). The proposed IoT system sends the ECG signals of the patients to the IoT (Thingspeak) cloud service. The analytic algorithm (PCA algorithm) runs in the Thingspeak -MATLAB cloud to classify the heart illness by comparing the received signal with various ECG signals stored in the Thingspeak channel databases.

This study is arranged into seven sections as follows: section 2 presents a survey of related works, section 3 discusses IoT platforms, section 4 introduces the principle of the PCA algorithm, section 5 introduces the Thingspeak based ECG data analysis system, section 6 introduces the details and components of the proposed system structure, section 6 illustrates the proposed system implementation and results, section 7 presents the conclusions of this work.

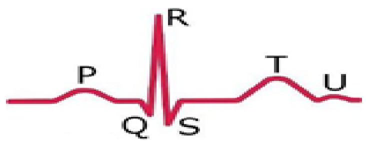

Figure 2. ECG signal from a healthy subject.

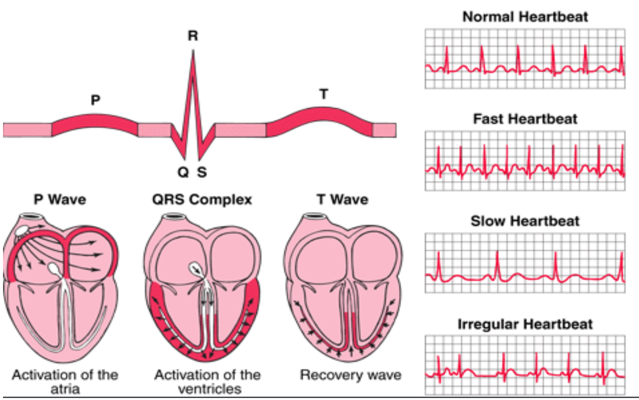

Figure 3. ECG signal samples.

2. RELATED WORKS

In [1], an application based on biomedical engineering (BME) was proposed. Wireless and mobile technologies are used to enable patients suffering from chronic heart diseases to live in their own homes and lead normal lives while being monitored for cardiac events. The proposed system [1] focuses on a heartbeat monitoring and alert system that can monitor the patient's heart rate. The system determines the heart beat rate per minute and sends a short message service (SMS) alert to the mobile phones of medical experts or the patient's family members.

A smartphone-based health monitoring system was presented in [2]. Using this system, healthcare professionals can monitor, diagnose, and advise their patients all at the same time. The field tests of this project show that our system can produce medical data that are similar to those produced by existing medical equipment. In [2], the blood pressure, body temperature, heart rate, and QRS intervals are included in the performance analysis.

In [5], a survey of IoT- based Patient Health Monitoring Systems was proposed by the researcher. This reference includes different technologies and IoT applications for health monitoring systems. An explanation and analysis of the technologies were provided, along with, applications, methods and implementation for the health monitoring system procedure in the medical field.

In [6], the researchers designed a project that could transmit data sensed from a remote patient to the doctor's PC using wireless transmission technology, (ZigBee). Using ZigBee, the data are received and displayed on the PC. If the doctors are not present nearby, they will receive an SMS on their mobile phones in case any of the parameters go beyond the normal range. The leads of the ECG sensor must stick properly to the patient, closest to the chest side.

A health monitoring system based on a LPC1114, GSM Modem, LCD and other hardware circuits was designed in [7]. In this study, the page messages were transferred at fixed time intervals to the corresponding medical expert to give necessary precautions and take care of the patient.

In [8], the researchers developed a patient monitoring system at low cost to reduce health care costs by reducing emergency room and physician office visits, hospitalizations, and diagnostic testing procedures. Many new wireless transmission protocols and technologies adapt easily to new applications. Their system was based on a Max232, 555 timer, GSM module, health care sensors, and AT89S52 microcontroller.

In [9], a healthcare monitoring system based IoT was designed and implemented to deal with brain tumors. The proposed system addressed in [9] uses the Thingspeak platform to run the Support Vector Machine (SVM) as a detection algorithm so, this work is contribute to make the IoT platform to deal with the machine learning and healthcare monitoring system.

3. THINKSPEAK IOT PLATFORM

Thingspeak is an open source IoT cloud platform that was launched in 2010 by ioBridge as a support service for IoT applications. “ThingSpeak is an IoT analytics platform service that allows you to aggregate, visualize and analyse live data streams in the cloud” [4, 9]. Thingspeak provides instant visualization of data posted by devices, and is also used for prototyping and proof of concept for IoT systems requiring analytics [9]. Thingspeak has many capabilities; some of its key capabilities include the following [9]:

- Easy configuration: configure devices to send data to Thingspeak using general IoT protocols.
- Visualization: visualize collected sensor data in real-time.
- Aggregation: aggregate data on request from third party sources.
- Analysis: run the automatic IoT analytics based on events or schedules.
- Prototyping: build and prototype IoT systems without setting up servers or developing web software.
- Automation: automatically manipulate the data and communicate using third party services such as Twitter® or Twilio®.

4. PRINCIPAL COMPONANTS ANALASIS

Principal component analysis (PCA) is a powerful technique that has been used for signal recognition. PCA is a mathematical procedure that transforms a number of (possibly) correlated variables into a (smaller) number of uncorrelated variables called principal components.

PCA is a statistical method that is used to reduce the large dimensionality of the data space to the smaller dimensionality of feature space. This method is used when there is a real and string relationship between the data spaces. The main idea of using PCA for signal recognition is to express the large 1-D vector of pixels into the compact principal components of the feature space. This process can be called Eigen space projection. Eigen space is calculated by identifying the eigenvectors of the covariance matrix derived from a set of facial signals (vectors) [10, 11]. The PCA algorithm steps can be summarized as follows:

- Take the whole dataset consisting of d-dimensional samples ignoring the class labels.
- Compute the d-dimensional mean vector (i.e., the means for every dimension of the whole dataset).
- Compute the scatter matrix (alternatively, the covariance matrix) of the whole data set.
- Compute the eigenvectors ($e1,e2,...,ed$) and the corresponding eigenvalues ($\lambda1,\lambda2,...,\lambda d$)
- Sort the eigenvectors by decreasing the eigenvalues and choose k eigenvectors with the largest eigenvalues to form a $d\times k$ dimensional matrix W (where every column represents an eigenvector).
- Use this $d\times k$ eigenvector matrix to transform the samples onto the new subspace. This process can be summarized by the mathematical equation: $y=WT\times x$ (where x is a $d\times 1$-dimensional vector representing one sample, and y is the transformed $k\times 1$-dimensional sample in the new subspace).

5. THINGSPEAK - BASED ECG DATA ANALYSIS SYSTEM

The structure block diagram of the proposed IoT ECG data analysis system is shown in Fig. 4. while Fig. 5 illustrates the prototype of the proposed system. The system is proposed as a multi-patient (in-patients and intensive care patients) monitoring system.

The proposed system is composed of the following parts:

A. ECG Sensor Nodes

Those nodes are distributed over patient and intensive care patient rooms. Each node is composed of ECG electrodes and a Node-MCU. The nodes are labeled with a unique ID corresponding to the patient’s name. The built-in, low-power WiFi module of the Node-MCU sends a json file of ECG raw data to a central broker at any time of day. Each file is composed of 128 samples.

B. Central Broker

The first role of the central broker is to collect raw ECG data from sensor nodes according to the timestamp (the patient ID is related to the data timestamp). The second role of central broker is sending the patient's ECG signal as a bulk data. Due to the number of field limitations of Thingspeak's channels (eight fields per channel), the central broker can send ECG data for six patients at a time (two fields serve as an ECG data base and for completion of data analysis) if one channel is used to implement the proposed system. To increase the number of patients, two channels were used to build the proposed system. The central broker sends one array of ECG samples (128 sample) for each patient. The importance of the central broker is in time scheduling of the patient's ECG data. The central broker can manage and send ECG data from fourteen patients to Thingspeak's fields with delay of 15 seconds at least between each sending. If the number of patients exceeds fourteen, the central server will enter a wait state and continuously read analytic state data from field number eight of channel number one. If the last data value is '0' for this field, then the analytic state of the last fourteen patients is not complete; if the last data value is '1' then the analysis is complete and the central broker can send another patient's ECG data. A visual basic based programming is used to implement the role of central broker with the pseudo code shown in Fig. 6.

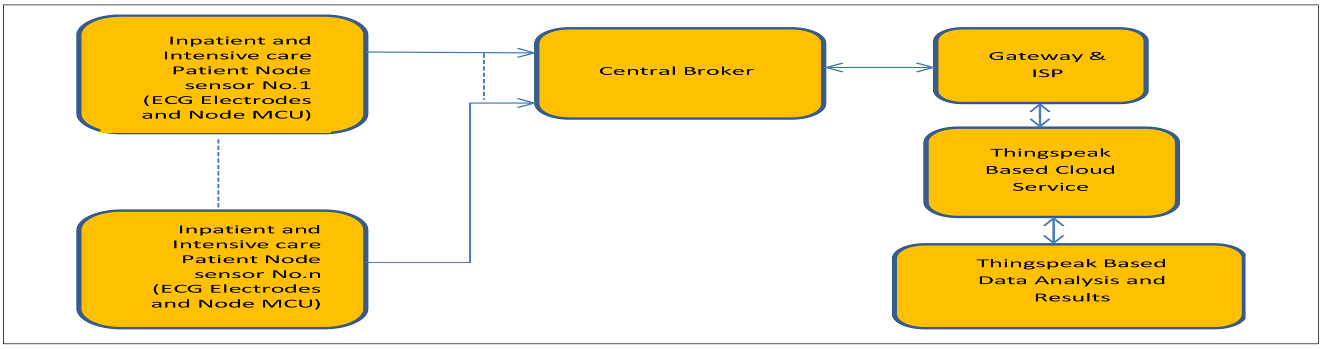

Figure 4. Structure of proposed ECG diagnose system

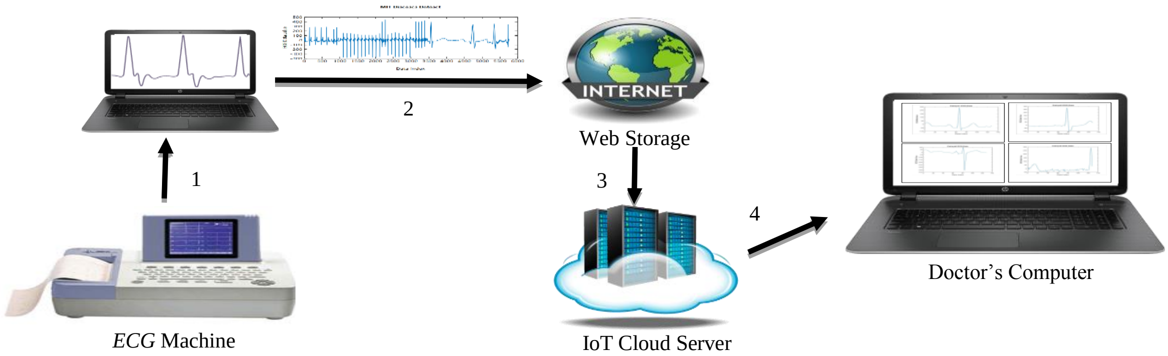

Figure 5. Prototype of the proposed system

```
Start
Program Send Bulk data to Thingspeak:
Specify the CSV files for patients;
Read the CSV files;
Save each file to an array;
For i=1 to patient n
Use web request from Client to Thingspeak;
Send array data with size 128 of [i] to Thingspeak;
Wait 15 seconds as a delay after each request;
    Is i reached max-value?
    yes: go to End of loop
    no: go to send array data
end loop
Use webClient from client to Thingspeak;
Does uploaded data are processed?
yes: go to start
no: wait 5 seconds
go to Start
End:
```

Figure 6. Pseudo code of the central broker

C. *Gateway*

This component is an intermediate service located between the central server and the Thingspeak-based cloud service. The gateway may be a master node, such as Node-MCU with AIT commands, or it may be a simple router for forwarding data to the Thingspeak service.

D. *Thingspeak-Based Cloud Service*

Due to the important merging between Thingspeak features and MATLAB analytic features, the Thingspeak-based cloud service is a good candidate for IoT healthcare monitoring systems. The central server sends patient's ECG data to the Thingspeak channel for 24 hours continuously according to the time scheduling scheme. A principal component analysis (PCA) algorithm was adopted to classify the patient's health status. The operator can visually access the data stream via Thingspeak channels with support from an automatic cloud- based diagnosis of the signal conditions by classifying the signals according to the disease datasets. For prototyping purposes, two Thingspeak channels were adopted to implement the healthcare system. The MIT disease datasets were used and loaded into field number two of channel number one. The disease datasets have four groups of diseases, and each group has 15 patterns with 128 samples each. A total of 5760 samples were uploaded to field number 2 of channel 1 (see Fig. 7). The types of those diseases in the data-set is shown in Table I. Field 8 of channel 1 was used for data process indication. The remaining fields (14 fields) of two channels are used to store patient ECG data. Fig. 8 shows an example of ECG signals uploaded to fields 1, 3, 5 and 6 of channel one.

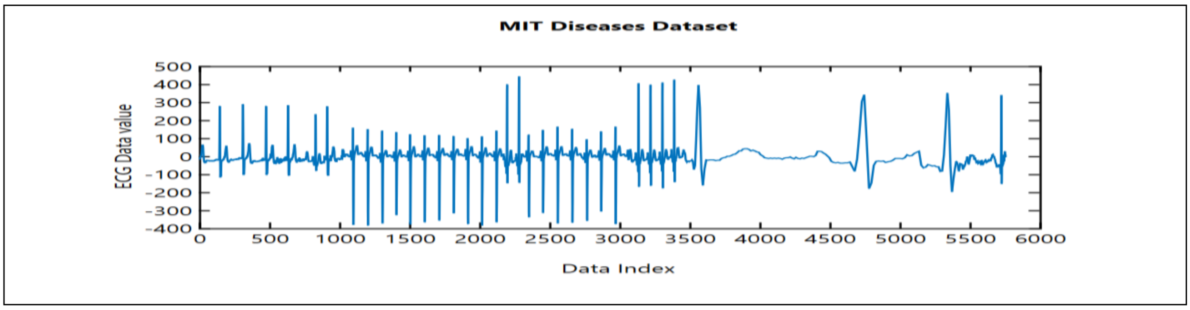

Figure 7. Data-Base stored in field 2 of channel 1

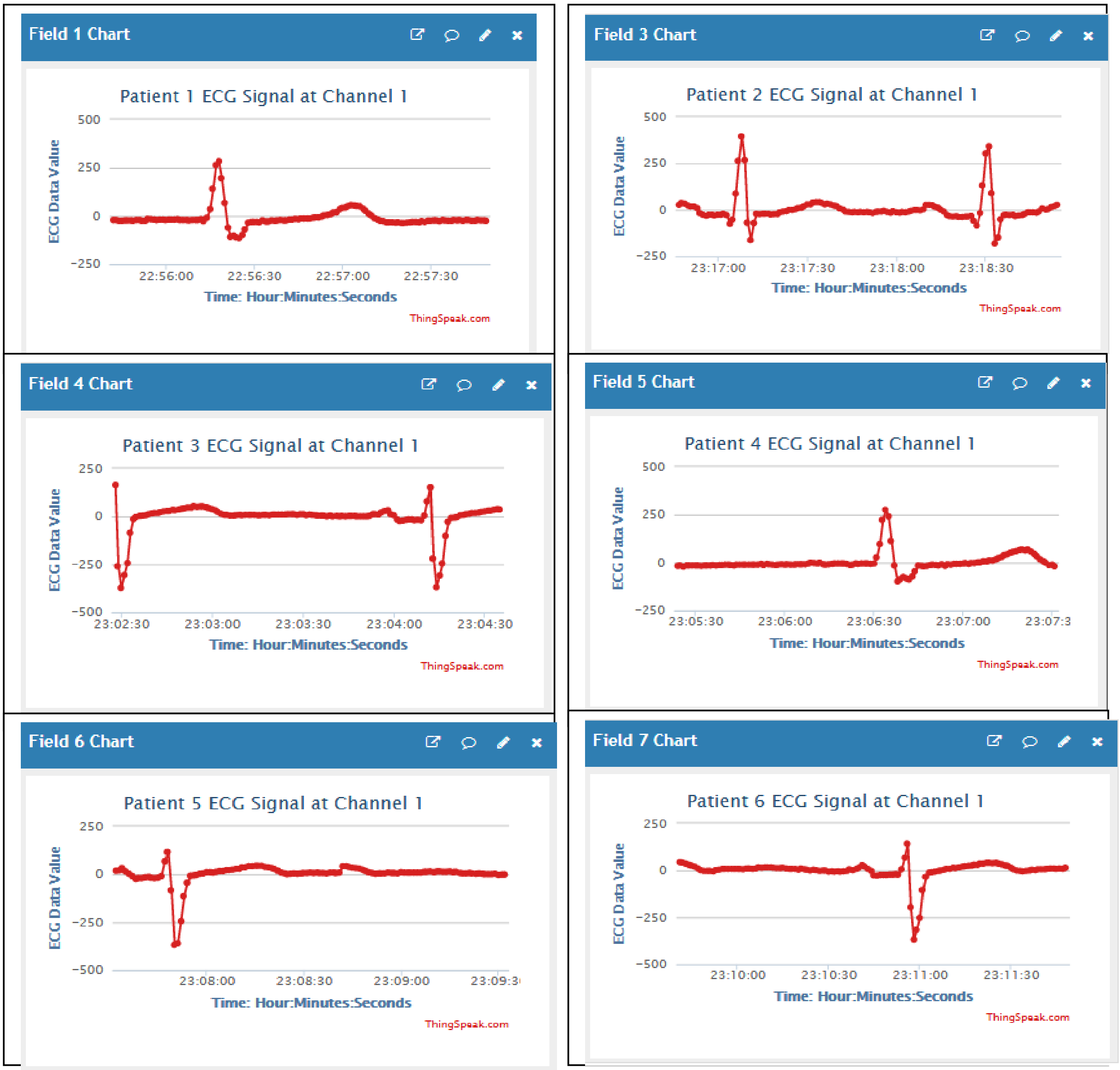

Figure 8. ECG signals uploaded to fields 1, 3, 5 and 6 of channel one.

6. SYSTEM IMPEMENTATION AND RESULTS

The proposed IoT ECG health monitoring system based on the Thingspeak platform is composed of two main parts as shown in Fig. 9. The first part is the ECG sensor nodes for ECG raw data acquisition via a Node-MCU with a WiFi built-in module and central broker. The data are collected, saved as text file type and forwarded to the central broker. The central broker is designed based on the Visual Basic programming language with a user-friendly command window for fourteen patients. The main role of this part is to schedule patients ECG data and forward those data to Thingspeak platform. The central broker encapsulate each ECG data signal as csv file and send the file to Thingspeak platform with time approximately 128 seconds (one second between each data value of the ECG signal). Table II shows the starting and ending time (GMT+3 Hours) of six ECG signals for six patients shown in Fig. 8.

The user can read the ECG data and forward those data to the Thingspeak platform after checking whether the previous patient's data have been processed successfully via the online MATLAB analytic program. The forwarded data are saved in fourteen fields of two Thingspeak channels. The second part is the online MATLAB program in Thingspeak platform. The program reads and processes the saved data using the PCA algorithm for classification purposes. A sample of Thingspeak-based online MATLAB code for the PCA classification of one patient with an ECG signal saved in field1of channel1 is shown in Fig. 10. Fig. 11 shows the results captured from the Thingspeak online program for fourteen patients with different diseases.

TABLE I. DISEASE GROUPS

Group Name	Disease Type
Group1	Arrhythmia-MLII
Group2	Atrial Fibrillation
Group3	Normal- Sinus

TABLE II. TIME SCHEDULING FOR SIX ECG SIGNALS

Patient No.	Start Time (GMT+ 3Hours)	End Time (GMT+3 Hours)
Patient 1	22:55:42	22:57:49
Patient 2	23:16:47	23:18:54
Patient 3	23:02:28	23:04:35
Patient 4	23:05:24	23:07:31
Patient 5	23:07:50	23:09:50
Patient 6	23:09:41	23:11:48

There are single obvious fault technical issue regarding patient 2, where the ECG signal of this patient belong to group one while the system designated it as group two. On the other hand, the other signals have been classified successfully according to their groups.

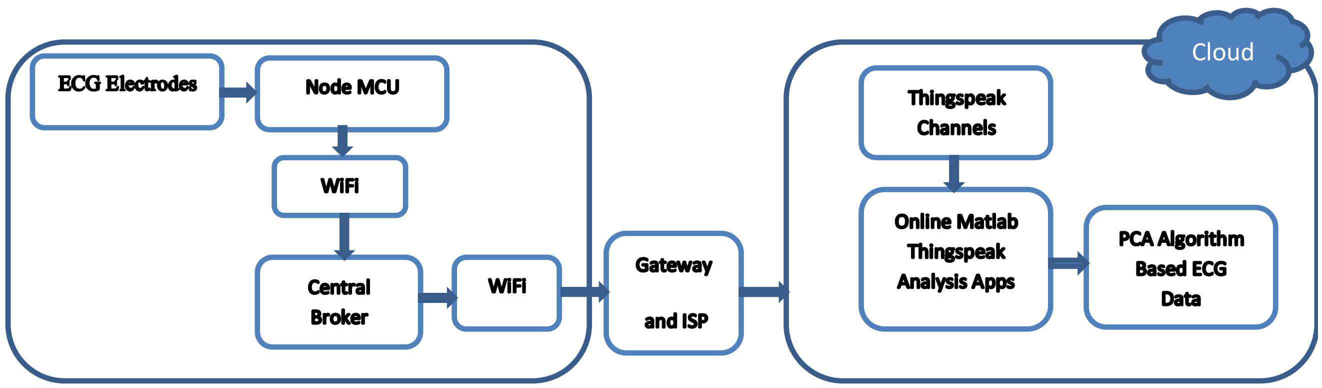

Figure 9. Structure of the proposed system.

```
readChannel1ID =199139; readChannel2ID= 381747; readAPIKey1 = 'JLY5BNZ0E7T8E61A'; readAPIKey2 = 'MM9Z3IFG8C1U1ERZ';
[ECG_Trained_Data, time] = thingSpeakRead(readChannel1ID, 'Fields',2, 'NumPoints',5760, 'ReadKey', readAPIKey1);
[ECG_Patient1_Data, time] = thingSpeakRead(readChannel1ID, 'Fields',(1), 'NumPoints',128, 'ReadKey', readAPIKey1);
thingSpeakPlot(time, ECG_Patient1_Data); T=[ ]; j=1;
for i=1:45
T(:,i)=ECG_Trained_Data(j:(128*i));
j=(128*i)+1;
end
[meanface,Normalized,Eigenfaces]=Eigenface(T); OutputName1 = Recognition(ECG_Patient1_Data, meanface, Normalized, Eigenfaces);
if size(ECG_Patient1_Data ~=0)
SelectedImage1 = strcat(OutputName1);
Output1=str2double(SelectedImage1);
 if(Output1<=15)
 disp('Patient1 Health Statuse is belong to First Group');
 end
 if(Output1>15 && Output1<=30)
 disp('Patient1 Health Statuse is belong to Second Group');
 end
 if(Output1>30 && Output1<=45)
 disp('Patient1 Health Statuse is belong to Third Group');
 end
end
thingSpeakWrite(199139,'Fields',[8],'Values',{1},'WriteKey','AO6TOOFTZ7DLPFDN');
function [meanface, Normalized, Eigenfaces] = Eigenface(T)
meanface = mean(T,2); Train_Number = size(T,2); Normalized = [ ];
for i = 1 : Train_Number
   temp = double(T(:,i)) - meanface; Normalized = [Normalized temp];
end
Coveriance = Normalized'*Normalized;  [V D] = eig(Coveriance); L_eig_vec = [ ];
for i = 1 : Train_Number
   if( D(i,i)>1 )
      L_eig_vec = [L_eig_vec V(:,i)];
   end
end
Eigenfaces = Normalized * L_eig_vec;
end
function OutputName = Recognition(x, meanface, Normalized, Eigenfaces)
ProjectedImages = [ ]; Train_Number = size(Eigenfaces,2);
for i = 1 : Train_Number
   temp = Eigenfaces'*Normalized(:,i);
   ProjectedImages = [ProjectedImages temp]; end
InputImage = x(1:128); Difference = double(InputImage)-meanface;  ProjectedTestImage = Eigenfaces'*Difference; dist = [ ];
for i = 1 : Train_Number
   q = ProjectedImages(:,i);
   temp = ( norm( ProjectedTestImage - q ) )^2;
   dist = [dist temp];end
 [Euc_dist_min , Recognized_index] = min(dist); OutputName = strcat(int2str(Recognized_index));end
```

Figure 10. Thingspeak based online Matlab code for one patient.

```
Patient1 is belong to second group
Patient2 is belong to first group
Patient3 is belong to third group
Patient4 is belong to third group
Patient5 is belong to second group
Patient6 is belong to third group
Patient7 is belong to third group
Patient8 is belong to first group
Patient9 is belong to third group
Patient12 is belong to second group
Patient13 is belong to second group
Patient14 is belong to second group
```

Figure 11. Results captured from the Thingspeak online program.

7. Conclusions

A Thingspeak cloud computing ECG diagnostic system is proposed based on an analytic MATLAB classification program. The analytic program is based on a PCA algorithm running on the Thingspeak cloud IoT platform. The proposed system provides a reliable healthcare monitoring system that can enable healthcare professionals to monitor their patients remotely through the cloud. All experimental set up and observations showed that the system was an effective solution for monitoring a patient's heart health. The doctor can access the data through the Thingspeak IoT cloud and run the analytic MATLAB program to classify the ECG signal from a patient and aid in the diagnosis. Implementation of this system allows doctors to monitor and improve the health of their patients. Notably this system allows a doctor to monitor more than one patient through the cloud.

REFERENCES

[1] Ufoaroh S.U , Oranugo C.O, and Uchechukwu M.E, " Heartbeat Monitoring and Alert System Using GSM Technology ", International Journal of Engineering Research and General Science (ISSN 2091-2730), Volume 3, Issue 4, 2015.

[2] Amna Abdullah, Asma Ismael, Aisha Rashid, Ali Abou-ElNour, and Mohammed Tarique, " Real Time Wireless Health Monitoring Applicatiob Using Mobile Devices ", International Journal of Computer Networks & Communications (IJCNC) Vol.7, No.3, 2015.

[3] Noor Kareem Jumaa, "Survey: Internet of Thing Using FPGA", Iraq J. Electrical and Electronic Engineering, Vol.13, No.1 - 2017.

[4] M. Sruthi and B. R. Kavitha, "A Survey on IoT Platform", International Journal of Scientific Research and Modern Education (IJSRME), ISSN(online): 2455-5630, Vol. I, Issue I, 2016.

[5] Rakshith Babu H V and Prof. Latha. S, " Survey of IoT based Patient Health Monitoring System ",International e-Journal For Technology And Research, IDL - International Digital Library Of Technology & Research Volume 1, Issue 6, June 2017.

[6] Sachin Singh and Netaji Gandhi.N, "Pattern analysis of different ECG signal using Pan-Tompkin's algorithm", International Journal of Computer Science and Engineering (IJCSE), Vol. 02, No. 07, 2010.

[7] Nagendra H, S. Mukherjee, and Vinod Kumar, "Application of Wavelet Techniques in ECG Signal Processing: An Overview", International Journal of Engineering Science and Technology (IJEST), Vol. 3, N0. 1, 2011.

[8] Purnima, Neetu Rout, Rahul Tiwary , and Renuka Bhandari, " ZIGBEE and GSM Based Patient Health Monitoring System ", International Journal of advanced Research in Electrical, Electronics and Instrumentation Engineering (ISSN (Online): 2278 – 8875), Vol. 3, Issue 1, 2014.

[9] www.thingspeak.com

[10] Kim K.," Face Recognition using Principle Component Analysis", In International Conference on Computer Vision and Pattern Recognition, pp. 586-591.

[11] J.Ashok and Dr.E.G.Rajan, " Principal Component Analysis Based Image Recognition", International Journal of Computer Science and Information Technologies (IJCSIT), Vol. 1 (2), 2010.

[12] J.Ashok and Dr.E.G.Rajan, " Principal Component Analysis Based Image Recognition", International Journal of Computer Science and Information Technologies (IJCSIT), Vol. 1 (2), 2010.

Auday A.H. Mohamad received his Ph.D. in Electrical and Electronics Engineering from Omdurman Islamic University, Sudan, in 2012. He received his B.Sc. and M.Sc. in Electrical Engineering (Computers and Control) from University of Baghdad, Iraq in 1997 and 2000, respectively. Currently, he is an Ass. Prof. (Computer Technology Engineering Department) in Al-Mansour University College-Iraq. Previously, he worked as lecturer (Electrical Engineering, 2000-2003) in College of Engineering- University of Baghdad, Iraq, and as Assistant professor (Electrical and Electronics Engineering, 2003-2013) in Faculty of Engineering Sciences- Omdurman Islamic University, Sudan.

Noor Kareem Jumaa received her M.Sc. in Electronics and Communication Engineering (Computer Engineering) from University of Baghdad, Iraq in 2013. She received her B.Sc. in Computer Engineering from University of Baghdad, Iraq in 2010.
Currently, she is a lecturer (Computer Technology Engineering) in Al-Mansour University College-Iraq. Previously, she worked as external lecturer (Computer Engineering, 2011-2012) and (Electrical Engineering, 2013) in College of Engineering- University of Baghdad, Iraq.

Samer Hameed Majeed received his M.Sc. in Computer Engineering from Cankaya University, Turkey, in 2014. He received his B.Sc. in Computer Engineering from University of Technology, Iraq in 2005.
Currently, he is an assistant lecturer (Computer Technology Engineering) in Al-Mansour University College-Iraq. Previously, he worked as telecommunication engineer in several national and international companies; such as Huawei, Ericsson and Itisaluna, Iraq.