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Smartphone-BasedIoTHealthcareMonitoringSystemforVitalSignalAnalysisandRemotePatientCare

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Abstract

Advancementsininformationandcommunicationtechnologieshavebroughtaboutaprofoundtransformation in the realm of healthcare. The downsizing of signal acquisition devices has facilitatedgreaterportability,yetthisdevelopmenthasalsopresentedchallengesintermsofpowerconsumption.To surmountthis,asolutionthatislightweightandpower-efficientbecomesimperative.Onesuchsolutioninvolvesharnessingthecapabilitiesofsmartphonestocollectand analyzevitalsignals.LeveragingInternetofThings(IoT)technologyenablestheremotemonitoringofdiversepatientparameters, accessible through a range of devices suchas computers and smartphones, facilitatedbycloudserviceslikeThingSpeak.Divergingfromconventionaltests,modernsensors,encompassing metricslikeheartrate,temperature,andSPO2,providedailyreadingsthatempowerdoctorstoremotelyprescribetreatmentsandexercises,therebyelevatingthequalityoflifeforpatients.Thisinnovativesystemoffersinstantaneous sensing,preciseprognostications,andswiftresponses,culminatinginstreamlinedhealthcarepracticesthatalleviatetheburdenonmedicalpractitioners.Instances ofanomaliesprompt alerts to caregivers. The trajectory of this approachportendsfurtherenhancements,encompassingadditionalmodulessuchasbloodpressuremonitoringanddentalscreening, to engender a comprehensive, real-time patient care continuum. This paradigm represents anotablestridetowardstheaugmentationof patientcaresystems.

Introduction:

Contemporary healthcare monitoring systems demand rapid sensing, meticulous prognostications, andimmediate interventionvia medicative measures. Thisentails the utilization of sensing modulesthatgauge critical parameters—such as body temperature, heart rate, and SPO2—and subsequently transmitthis data to a central computing system, thereby facilitating the remote analysis of a patient's healthcondition. This pivotal development not only lightens the load borne by medical practitioners but alsofurnisheshighlyaccurateresults.ThedatainputsaremeticulouslyscrutinizedthroughanIoT

framework, andanydeviations fromthe norm thata patientmay experience prompt the monitoringsystemtodispatch anIoTalerttothedesignatedcaregiver.

ResearchMethodology:

Withintheconfinesoftheexistingsystem,manualadjustmentstoparametervaluesarethenorm.However, when these values approach their upper thresholds, the system promptly notifies stakeholderseither through alarm signals or messages. This proactive approach serves to optimize the efficacy ofmedical personnel within the hospital, ensuring timely interventions that could potentially save lives.Wireless telemedicine, also colloquially referredto as mobile health, harnesses the advancements inwirelesstechnologiestoestablishaseamlessconduitforhealthcaredeliveryandtheexchangeofmedical data, transcending geographical, temporal, and logistical constraints. This innovation facilitatesremotediagnosis,continuousmonitoring,andseamlesstransmissionofmedicaldataandrecords.

The incumbentsystem features a PIC microcontroller-based wireless technology,depicted in Figure 1,andemploysGSMtechnologyandsensorarraystofacilitatereal-timemonitoringofapatient'sphysiologicalparameters.Furthermore,itfacilitatesthetransmissionofmedicaldata andpromptlynotifiescaregivers.Ofparamountsignificanceistheincorporationofarecordingsystemthatcompre hensively documents the patient's health history, culminating in a comprehensive repository ofhealthrecords.

The human body offerstwo primary locations for measuringheartrate:the right side wrist andtheneck.Thismethodinvolvesplacingtheindexandmiddlefingersoneitherthewristortheneck,beneaththe windpipe, and counting the pulsesfor 30seconds. By multiplyingthe pulse count by two,the heart rate can be determined. For accurate results, it's essential to apply minimal pressure duringmeasurement. Gentle movement of the fingers can help locate the pulse rhythm. Alternatively, sensortechnologycapitalizesonthedisturbanceoflightasittraversestheblood'spath.Thisdisturbancecausesfluct uationsinheart rate,whichcan bemeasured.

Heart rate, denoted in beats per minute (bpm), represents the pace of heart contractions. The normalrhythm, known as sinus rhythm, typically ranges from 50 bpm to 90 bpm based on the body's physicaldemands and activities. The regulation of heart rhythm involves the exchange of sodium and potassiumions.Variousfactorssuchashyponatremia(lowsodiumionconcentration),hypokalemia(lowpotassiu m ion concentration), hypothermia (low body temperature), hypoxia (low oxygen supply to thebody), and acidosis (low pH value with elevated hydrogen ion concentration) can impact this rhythm.Monitoringheartrhythmisessentialtosafeguardindividualsagainstthesefactors.Heartratemeasuremen tisfacilitatedthroughwristheartratemonitorsandheartratesensors.Thesesensorsdetect

andmeasure the heartrhythmwithin thebody. Whileheart rate canbeassessedindifferent bodyregions,thisresearchfocusesonutilizing theapexoftheforefinger.

The heart rate detector operates by synchronizing the flashing of a LED with each heartbeat. The digitaloutputgeneratedcanbedirectlyconnectedtoamicrocontrollerfordeterminingthebeatsperminute.Thedev iceoperatesontheprincipleoflightmodulationbybloodflowwithinthefingerduringeachpulse. The sensor incorporates a high-intensity light source to maximize light transmission through thefinger, which is then detected by alight sensor.As theheart pumps blood, the finger becomes slightlylesstransparent,leadingtoreducedlightreachingthesensor.Thismodulationresultsinelectricalpulses, which are amplified and processed by an amplifier to yield a +5V logic level signal. A LEDindicator also flashes with each heartbeat, utilizing a technique termed "Photo Plethysmography." Thistechnique capitalizeson the light's interactionwithbodily organs,where intensity variationsconveyorganconditions.Bloodvolumechangesaccordingtolightintensity,correlatingwithheartpulse rhythms.

The heartbeat sensoremploys Phlethysmography, basedon thealterationin blood volume withinabodily organ causing corresponding changes in light intensity. In heart rate monitoring applications, thetiming of pulses is crucial. Blood volume flow corresponds to the rate of heart pulses, and since bloodabsorbslight,thesignalpulsesalignwithheartbeatpulses.Alight-dependentresistor(LDR)servesasthe light detector, with its resistance altering based on light intensity. A comparator, specifically anLM358, compares theLDR's output voltage to athreshold voltage.Whenhuman tissue isilluminated,thedecreasedlightintensitypromptsincreasedresistanceandvoltagedropacrosstheLDR.Thiscom parison generates a series oflogic highand low signals, representingpulse intervals.These pulsesarefedtoamicrocontroller,whichprocessesthedatatocalculateheartrate,subsequentlydisplayedonaconn ectedinterface.

The work proposed by Purnima Puneet Singh et al., [1] healthcare monitoring system that uses GSMtechnologytogather vitalhealthparameterslike bodytemperature, heart rate,andsweatrate.Thesystemanalyzesthe inputs through a microcontrollerplatform and sends messages tocaretakers incaseofabnormalities.ThefocusofMelanieSwanetal.,[2]onIoT-basedhealthmonitoringsystemscollectingdatasuchastemperatureandpressure.Thistechnologyhasreducedrou tinecareneeds,makingremotemonitoringofnon-severeCOVID-19patientspossible,eveninquarantinesettings. The Matina Kiourexidou et al., [3] highlights the need for a portable healthcare system to provide basichealth parameter readings in remote areas. This system transmits data to doctors, allowing treatmentwithouttravelandassistinginemergencies.ThestudypresentedbyPoltakSihombingetal.,[4]methodto measureheartrateusingapulsesensor,Arduino,andanAndroidsmartphone.Thetooldetectsheart

rate by monitoring blood volume variations, displaying the results on an Android screen. The paperproposedbySushmaPawar,P.Kulkarnietal.,[5]describesawirelesssystemusingAndroidsmartphones to collect vital signs like body temperature and ECG. The data is processed using an ARMprocessoranddisplayedondoctors'orrelatives'smartphonesandpersonalcomputers.

Praveen Halapeti etal.,[6] focusedonpregnantwomen'shealth,thisresearchemphasizes wirelesssensors to monitor blood pressure, heart rate, and fetal movement. The wireless body sensor networktransmits signals to a base station for analysis. Benhauddu et al., [7] introduces MACH, a scheme forhealthcaresensornetworksthatensuresqualityofservice,particularlyforemergencytraffic.Thesystem extends medical applications to underserved areas through sensor networks. The Vikramsingh RPariharetal[8]studypresentsacomputer-basedheartratemonitorusingArduinoandapulsesensor.The Arduino board transfers pulse signal data to a computer application, displaying the heart pulse rateusingphoto-plethysography(PPG).

IoT-based smart health monitoring system proposed by VaneetaBhardwaj et al [9] measures bloodpressure, heartrate, oxygen level, andtemperature. High-speed internetand cloud storage allow real-time data collection, aiding doctors in diagnosis and treatment. The research focusedbyMohammadMonirujjaman Khan et al., [10] on a healthcare monitoring system for various patients, including thosewith COVID-19, high blood pressure, and diabetes. It measures body temperature, heart rate, and bloodoxygenlevels,transmittingdatatoamobile app viaBluetooth.

ProposedWork

The IoT patient monitoring has 3 sensors. The first one is a Heartbeat rate monitoring, the second is theSPO2, and the third is Temperature Sensor. It is very useful since the doctor can monitor patient healthparameters just by visiting a website or URL. And nowadays many IOT apps also being developed. Sonowthedoctororfamilymemberscanmonitorortrackpatientshealththroughtheapps.

To operate an IOT based health care monitoring system so you need a Wi-Fi connection. The arduinoboards connect to the Wi-Fi network using a Wi-Fi module. This project will not work without Wi-Finetwork. You can create a Wi-Fi zone using a Wi-Fi module or you can even create a Wi-Fi zone usinghotspotonyoursmartphone.ArduinoUNOboardcontinuouslyreadsinputfromthese3senses.Thenitssends thisdatatothecloudbysendingthisdatatoaparticularURL/IPaddress.Thenthisactionofthis sending datatoIP is repeated aftera particular interval of time.Forexample.Inthisproject, wehavesentdataafter every30seconds.

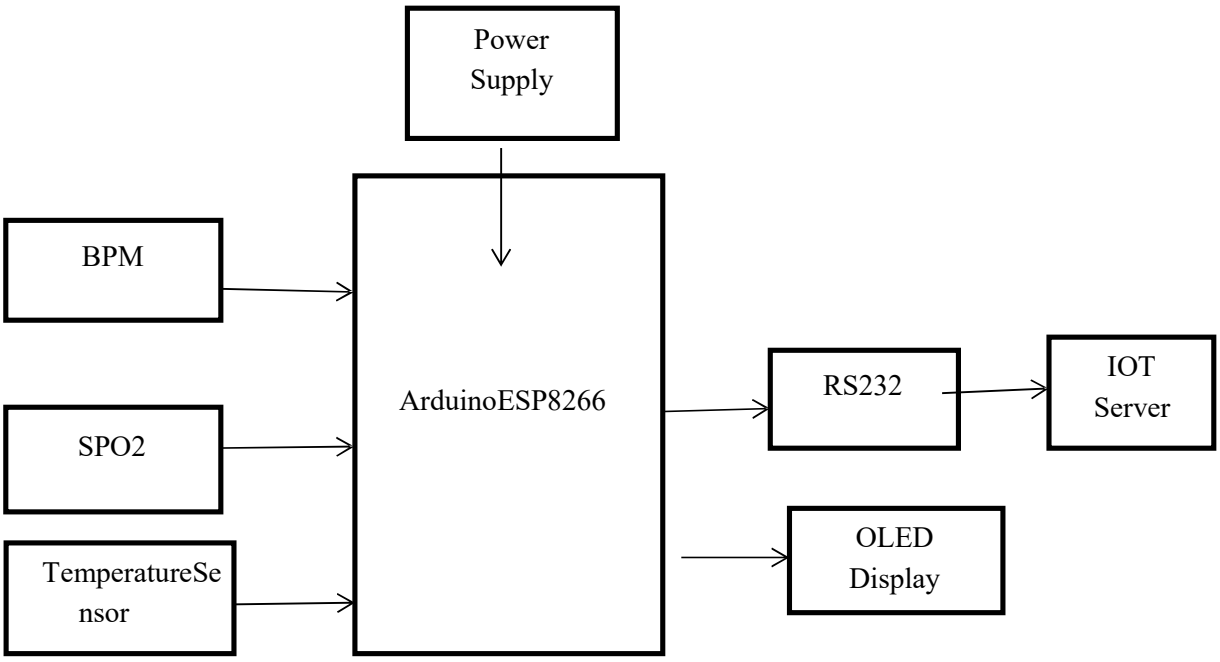

Figure1BlockDiagramofProposedSystem

Arduino collects real-time health data from a pulse sensor that measures heart rate in minutes or BPM(beats per minute). An Arduino digital temperature sensor measures the patient's body temperature. ThestandardESP8266IoTmoduleconnectstoArduinoviaUART,isresponsibleforconnectingthemachinetotheinternetandsendinghealthdatatotheIoT(Thingspeak)serverforstorageandmonitoring. This region can not only send patient health data to the server but can also display real-timedata onan OLED display. This is helpfulfor health care professionals who actively monitor the patientonsiteisshowninfigure1.

HARDWAREDESCRIPTION

Thehardwarerequiredforthisprojectare

- Arduino
- Pulsesensor/Heartbeatsensor
- MAX30102
- ESP8266
- OLEDdisplay

PROPOSEDWORK

Initially the three different sensors includestemperature, heartbeatsensor, SPO2 the body condition ofthe humansand sends message to the doctors or caretakers tomonitor the patient'shealth. We canmonitorthembyanalysingtheparametersreceivedfromthesensorthroughcomputeranddothenecessaryimmediateactiontothepatientswhichreducestheworkloadofdoctors.Itconsistoftransmittingunitandreceivingunit.Thetransmittingunitisplacednearthepatientandreceivingunitisplacednearthedoctors.

The arduino gains the parameter values from sensor in form of voltage and it compares with predefinedvalue.If it not matches, the receiver unitwill receivesthe signaland itintimatesthrough alarm .Thenthe patient could be easily treat according to his body condition. In the system, various call forwardoptions,barringoptions ofincomingcallsor going outcalls.

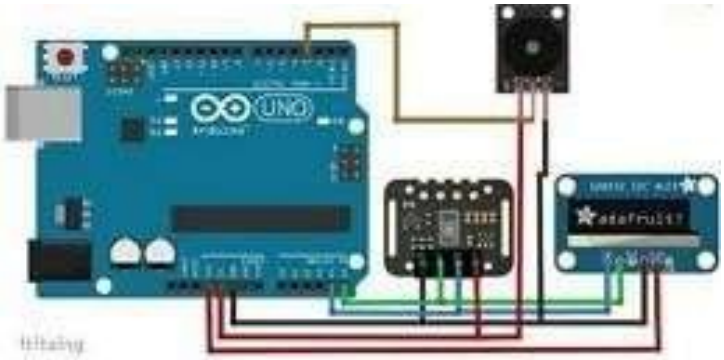

Figure2Experimentalsetup

Thisisalsodonewhentravellinginanothercountry.Severaladdonescanbeaddedasmultiplechannels, identification of a call, conference proceedings through phone etc. The conversations can bemade torecordfor flexible recallingthe data fortherequirementsandanalysispurpose isshowninfigure 2.

SOFTWAREDESCRIPTION

Thinkspeak

It is an open source software written in Ruby which allows user to communicate with internet enableddevice. It facilities data access, retrieval and logging of data by providing an API to both the device andsocialnetworkwebsites.ThinkspeakwasoriginallylaunchedbyIoBridgein2010asaservicein

support of IoTapplications. There are sensorsallaround—in our homes, smartphones, automobiles,cityinfrastructure, and industrial equipment. Sensors detect and measure informationon all sorts ofthingsliketemperature,humidity,andpressure.Andtheycommunicatethatdatainsomeform,suchasa numerical value or electrical signal. In this project, we are going to send the MAX30102 temperaturesensordatatoThingSpeakusingtheESP8266.ThingSpeakisbasicallyanIOTplatformthatletsusstor ethedatainthecloudanddevelopinternetofthings(IOT)applications.Wewillcreateachannelon ThingSpeak, and after connecting the ESP8266 to our Wi-Fi network, we will send the data to theThingSpeak IP address andAPI key.Forconnecting theESP8266 with Arduino, we have usedtheESP-01 adapter, which makes connecting much easier. Using this adapter, we don't require the voltagedivider circuit or any external power, because this adapter has a built-in voltage regulator. Connect theVCC of the ESP-01 adapter to the 5V of Arduino and GND of adapter to the GND of Arduino. Thenconnectthe TXof the adapter to pin 2of Arduino, and the RXof the adaptertopin 3of Arduino.Sensors, or things, sense data and typically act locally. ThingSpeak enables sensors, instruments, andwebsites to send data to the cloud where it is stored in either a private or a public channel. ThingSpeakstoresdata in privatechannelsbydefault,butpublic channels canbe usedtoshare data withothers.OncedataisinaThingSpeakchannel,youcananalyzeandvisualizeit,calculatenewdata,orinteractwit hsocialmedia,webservices,andotherdevices.

- Storing data in the cloud provides easy access to your data. Using online analytical tools, youcanexplore and visualize data.Youcan discover relationships, patterns,andtrends in data.Youcancalculatenewdata.Andyoucanvisualizeitinplots,charts,andgauges.
- CreatingaChannelonThingSpeakFirst,gotoThingSpeak.comandclickon"GetStartedforFree".
- The sign-up form will come up. Enter the information required and sign up for ThingSpeak isshowninfigure3.

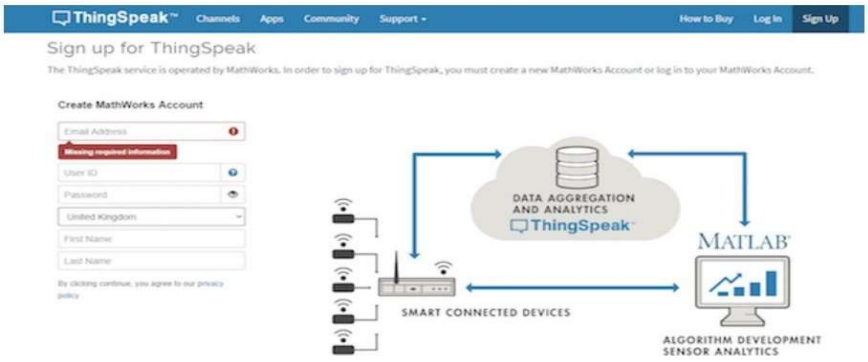

Figure3Thinkspeak

7

- Afterthat,clickon“NewChannel”tocreateachanneltostoretheinformation..

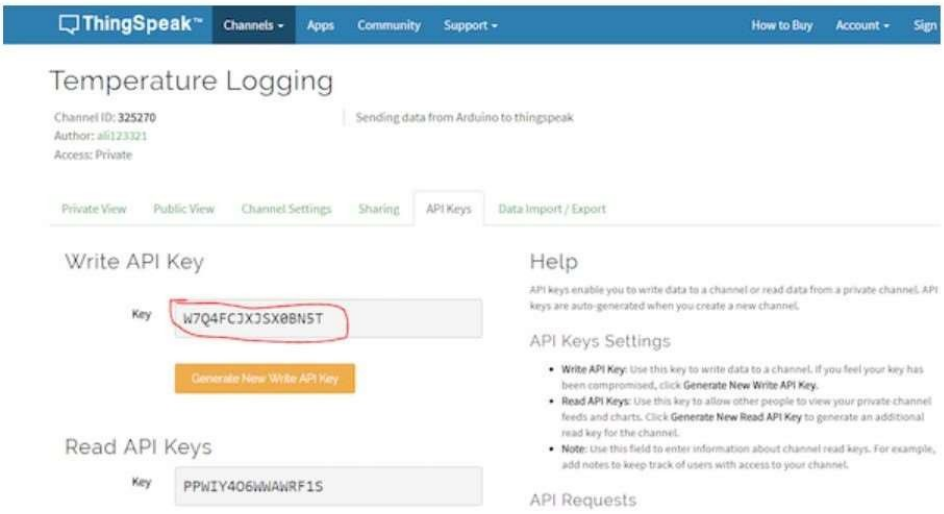

Figure4ThinkspeakChannelcreation

- Then enter the information about the new channel as I have done below, and leave the otherinformation asitis. After that,gototheAPI keyssectionandcopyyour writeAPI key isshowninfigure4.
- Youwillneedtoenterthisinthebelowcode

ThingSpeakprovidesaccesstoMATLABtohelpyoumakesenseofdata.Youcan:

- Convert,combine,andcalculatenewdata
- Schedulecalculationstorunatcertaintimes
- Visuallyunderstandrelationshipsindatausingbuilt-inplottingfunctions
- Combinedatafrommultiplechannelstobuildamoresophisticatedanalysis

The measuring parameters like temperature of body, beat rate of heart,SPO2 and transfer it to thecomputer so that health condition of a patient can be analysed remotely. Thus, it reduces the doctor’sworkload and also gives accurate results. Further this system uses IOT technology which enables themonitoring of all parameters on the mobile phone. The inputs areanalysedthroughIOT platform fromthe patient and any abnormality felt by the patient causes the monitoring system to send an IOT to therespected caretaker. These are the essential data for the future analysis and review of patient’s healthcondition.Thismaybeaddedwithadditionalfeatureslikemonitoringpressureofbloodmodules,dental screening modules etc. so as to make this a very real time application oriented device. This willenhance the another stepping stone towards patient care systems. It has integrated support from thenumericalcomputingsoftwareMATLABfromMathworks,allowingthinkspeakuserstoanalyseand

visualizeuploaddatausingMATLABwithoutrequiringpurchaseofaMATLABlicensefrommathworks.

EXPERIMENTALRESULTSANDCALCULUS

Internet of Things (IoT) is a concept that aims to expand the benefits of connected internet connectivitycontinuouslytheabilitytosharedata,remotecontrol,andetc,aswellasanobjectsintherealworld.Forexample,food,electronics,collectibles,anyequipment,includinglivingthingsthatareallconnectedtolocalandglobalnetworksthethroughembeddedandactivesensorspatienthealthparameter data is stored over the cloud. So, it is more beneficial then maintaining the records on printedpaper kept in the file. Or even the digital records which are kept in a particular computer or laptop ormemory device like a pen drive. Because there are chances that these device can get corrupt and datamightlost.

HeartRateMonitoringwithThingSpeak

In the IoT Heart Rate Monitoring with ThingSpeak Platform tutorial, we set up the heart rate sensor orpulse sensor using a Wi-Fi board that uses the ESP8266 chip. We then transfer the information receivedfromthesensortotheIoTplatform.Ofcourse,youhaveoftenseenconnectingthissensorwithdifferentboards, including Arduino.But thisproject is differentfrom other examples.Inthis project,usingtheESP8266boardandtheWi-Ficapabilityofthischip,wewilldisplayalltheoutputvaluesinthe IoTplatformcalledThingSpeak.

Thisplatformallowsustobuildadashboardwiththeabilitytomonitorthevaluescomingfromdifferent IoThardware.Andinthisproject,using thisfeature,we willmeasure the heartrate ofapersonusingarelevantsensoranddisplayitasagraphonthisdashboard.Inthisprojectwehaveuseda pulse sensor. Just placethesensoron thesurface of the skin or youcanalsoplace afinger on top ofthissensortogetthe values.

Figure5BPM

We have connected the sensor withESP8266 board as per the connection diagram.Oncewepowerupthe hardware and keep the finger on top of the sensor, it starts capturing and sending the data to IoTplatformisshowninfigure5.

It shows the heart rate pulse data in a chart and also in a Gauge. After you upload it, make sure that theWi-Fiused connectedwith internetconnection. Then, open serialmonitoring to seeatcommanddata.Data which sent is a random data. You can change it with data of sensor or etc. Here is the value ofmonitoringresult aftermany dataprocessing.

SPO2monitoringwiththinkspeak

The ESP8266modulesreadsraw sensor data froma MAX30102sensor at25samples/second.Thesampleareinsertedintoacircularbuffercontainingthelast125samples.SPO2arecomputer30timespersecondsusingRobertFraczkiwiczprocedureisshowninfigure6.

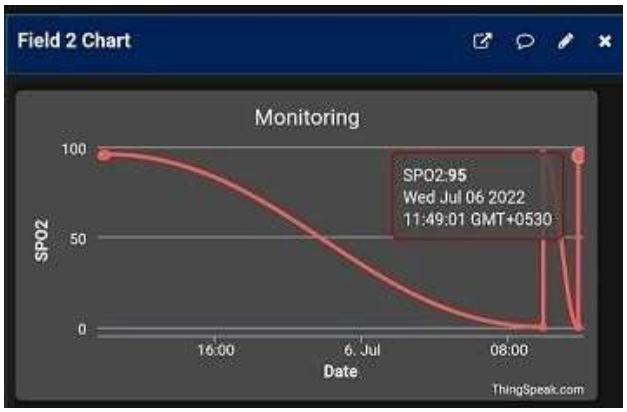

Figure6SPO2

Filteredreadingsarepublishedtoyourpersonalchannelontheiotwebsitethinkspeak,withaconfigurable update interval. We can view a 'Real-time' chart of the dataon our Thinkspeak channelpage.ItshowstheSPO2datainachartandalsoinaGauge.Afteryouuploadit,makesurethattheWi-Fi used connected with internet connection. Then, open serial monitoring to see at command data. Datawhichsentisarandomdata.Youcanchangeitwithdataofsensororetc.Hereisthevalueofmonitoringresult aftermany dataprocessing.

BodyTemperaturemonitoringwithThinkspeak

The MAX30102hasanon-chip temperature sensor that can beusedto compensate for the changes inthe environment and to calibrate the measurements. This is reasonably precise temperature sensor thatmeasurethedietemperatureintherangeof-40degreeCelsiusto+85degreeCelsiuswithanaccuracyof±1degreeCelsius.

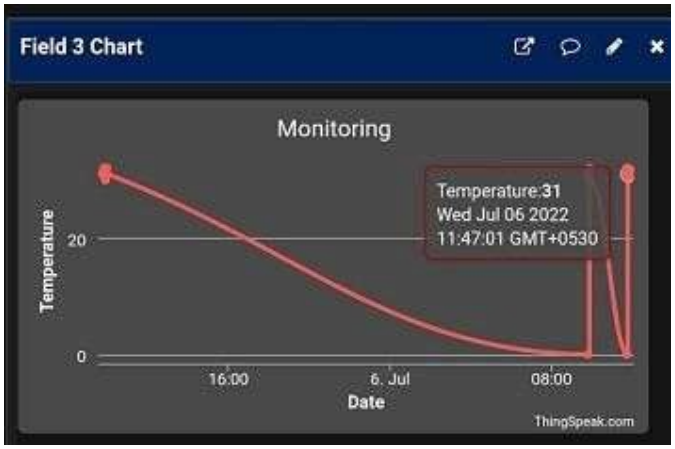

Figure7BodyTemperature

ItshowstheBodytemperaturedatainachartandalsoinaGauge.Afteryouuploadit,makesurethatthe Wi-Fiused connectedwith internetconnection.Then, openserial monitoring to see atcommanddata.Datawhichsentisarandomdataisshowninfigure7.Youcanchangeitwithdataofsensororetc.Her eisthevalueofmonitoringresultaftermanydata processing.

Open the private view tab on the thinkspeak channel to see your temperature graph plotted with the datasentfromthermometer.Youcancross-checkthe graphreadingswiththe temperature valuesbeingprintedonyourterminal.

CONCLUSION

The proposed system enables to evaluate the performance of the doctors in the hospital and alsothe patient can be treated truly and save their life. From this proposed system, the love fit ofmaking the patient towards the awareness of healthy life style is also initiated. By incorporatingthe blood pressure sensor and dental care monitoring systems the progression of the system isupgraded in the future for the health monitoring system. By proper precise experiments, theysystem may be incorporated into real time environment in the hospital which may save lives forseveralpatients.Thequick,accuracyandrealtimemethodologiescanbeimposedtotheproposed system to make this system into more efficient. The cost reduction also one of the mainkey factor focus to adopt thissystem to all levels of patients irrespective of their level ofdiseases.

IoT was defined as main distributor of health care systems as one of IoT most important uses.Helps to better to provide people with healthcare at any time in any region by eliminatinggeography, time and other barriers while increasing their coverage and efficiency at the sametime.Cloudcomputing,throughitsBase,isapromisingapproachforefficientknowledgeprocessing in the health sector. The framework provided is special and can be used to handlecloud device and network data specific to a patient. Built on IoT and its design principles, thecloud app allows for direct communication of sensor devices while at the same time making itversatile andeffectivetoservestoreddata,usersandsensors.

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