# IMPLEMENTATIONOFIOT TOSTOREPATIENT DATA GLOBALLY FOR CHRONIC KIDNEY DISEASE(CKD) PREDICTION

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## Abstract:

Chronic Kidney Disease (CKD) is a growing global health concern, and early detection is crucial for effective management. The integration of Internet of Things (IoT) technologies offers a transformative approach for continuous monitoring of CKD patients by collecting real-time data on vital health parameters such as blood pressure, glucose levels, and kidney function biomarkers. This paper presents the development and implementation of an IoT-based system for storing patient data globally and predicting CKD progression. The proposed system utilizes wearable sensors and remote devices to monitor patients continuously and uploads the data to a secure cloud-based platform for global access. The cloud infrastructure ensures the storage and retrieval of patient data, allowing healthcare professionals to track and analyze health trends remotely. Additionally, machine learning algorithms are applied to the stored data to predict the onset and progression of CKD, facilitating early intervention and personalized treatment plans. The system aims to improve CKD management, reduce healthcare costs, and provide a scalable solution for global health monitoring. By leveraging IoT, cloud computing, and machine learning, the system enhances decision-making and patient care while enabling collaborative research in CKD management worldwide.

## Keywords:

Chronic Kidney Disease (**CKD**), Internet of Things (**IoT**), Patient data storage, Cloud computing, Machine learning.

## 1.INTRODUCTION

"Internet of Things (IoT)" is the term coined for amalgamating different technologies together for achieving an advanced communication system. Different technologies like sensors, actuators, tracking devices, artificial intelligence, and many more are included in IoT. It not only connects the users through the internet but also helps in handling data sent by the user.Itisachievedwiththedevicenamed"ESP-8266"which is nothing but a Wi-Fi module interfaced with a microcontroller to achieved van cement in data handling. IoT proved its worth in different

fields of telecommunication, embedded systems, informatics, etc. The base ideology behind the IoT and its connectivity is that any devices with on and off-control actions can be a part of it. The devices that can be connected are mobile phones, laptops, home appliances, and many more with the internet.

### 1.1 IOT-AGatewaytoEvolvedCommunicationSystem

Ideally, IoT is applicable in all the fields of science and technology. But the research requirement is for developing an emotional recognition system with a data handling setup. The main theme for the application of IoT to this part of research is that thecreatininemeasuringemotionalrecognitionsystemsensesthecreatininevalueofthepatients and these data must be transferred and stored in some secure place so that the dataassessmentcanbedoneatanytimeandanywhereacrosstheworld.So,forthisissue, IoT acts as a tool to store data in a server and enables data access to the user anytime.

ThedevelopmentofIoTtookplaceintheyear1982whentheCokemachinewas loaded with bottles. This was the first machine to be connected to the internet and was doneatCarnegieMellonUniversity.Itcouldreportwhetherthebottlesloadedwerecold or not [1]. In the year 1991, Mark Weiser was the scientist who proposed the concept of "ubiquitouscomputing".Thiscomputertechniquehelpsinconnectinganydeviceapartfrom computers to the internet and anywhere and anytime [2]. Later in the year 1999, a device-to-devicecommunicationwasdevelopedbyBillJoy.Alongwiththisidea,Kevin AshtondescribedIoTasinterconnecteddeviceswiththeinternet.RFID(radio-frequency Identification) was the base idea behind IoT. In 2005, home automation, industrial automationwasimplementedviaIoT[1].ItwasproposedthatIoTcouldbeimplemented eveninhealthcare.Itwasobservedthatthesensors,actuators,communicationdevicesall werecontrolledthroughtheinternet.Thiscouldhelptoworkinavirtualenvironmentand control the real environment with much ease. No longer computing would be limited to computers [3]. E-healthcare and remote healthcare run with the help of IoT. To advance the level of communication 4G (fourth generation) high-speed internet was introduced whichwasevenappliedtohealthcarecommunicationsystems.Laterslowlytelemedicine came to the picture where the physicians guide their interns through video calling and assist them throughout surgery, medications, and tests [4].

Through IoT different devices get connected and their data are collected and furtherprocessed.An ideawas proposed tohelpthepeopleinthefieldofhealthcareand

aidthemincaseofemergencyasitisveryimportanttoassesstheIoTdataglobally.Here the IoT data is stored and then interpreted which can be helpful during an emergency. Finally, resource-based data accessing was devised with the help of IoT and computing. It was concluded that this method was very effective in database management systems [5].Asystemwasdevelopedinordertodeterminethesuccessrateofthecompanieswith the help of customer lifetime value. This IoT-based system personally approaches the customer and knows the credits of the products and then determines the worth of the productanditscompany.Italsohelpsinimprovingtheserviceoftheproductconcerning the customers' reviews about the product.

SmarterCommerceCustomerEngagementArchitecture(SCCEA)wasdeveloped withthehelpofe-commerce,IoT,andcustomerengagement.Similarmethodologiesare applied for healthcare with the SCCEA system [6]. RFID is a prerequisite to IoT. The features of RFID technology are that the cost of implementation is low when compared toIoT.Buttherangeofstorageiscomparativelyless.Asystemwasdesignedthatsenses theuser'shealthconditionaswellas theuser'senvironment liketemperature,creatinine low, and other gases with the sensors. This experimentation was done with the help of disposable sensors, low power devices, and many more [7]. An IoT-based system was developedinordertosensethemovementinParkinson'sdisease(PD)patients.Alightweightsensorwasd evelopedandwasfixedinthepatient'scloth.Thissensorwould sensethemovementofthepatientanditisconnectedtoatabletormobilephonethrough which it is finally connected with a medical database. IoT database not only provides storage of patient's data while visit but also for regular diagnosis at home. Through this system development, patients' comfort can be determined and their health can be consistentlymonitored.Thissystemalsohelpsthepatientstohelpthemselvesbysharing their experiences with the physicians as well as peer groups. It gives great comfort to a patient that they always care and their health status is always monitored and during any emergency, they can be easily treated [8]. With the development of IoT in medical science,newtechnologieslikecloudcomputingandbigdataarealsoemerging.Asystem wasdevelopedinsuchawaythatitincludedalltheadvancedfeaturespresenttoday.This is a sensor and a measurement system.

The sensor is made from a fabric material attached to the washable clothes. It senses the subject's physiological signals and helps to determine the health status of the subject along with a determination of the emotional state of the subject [9]. For treating chronically ill patients an instrument was developed in the name of Interactive Telecare System (ITCS) which connects the

caregiver's smartphone with the chronically ill patient's medical devices which assist them. This is done with the help of IoT and then all the devices are interconnected globally. Even in the absence of the caregivers the medical devices assisting the patients can be activated with the help of the caregiver's smartphone through IoT. Experimentation was done with the help of glucose monitor in sugar patients and then with the help of ITCS, it was observed that most of the medical institutions find it advantageous to work with ITCS system and gave positive feedback on such IoT based Telecare systems [10].

Mostly in all the sectors, IoT plays a crucial part. Sectors like agriculture, manufacturing,utilities,transportation,healthcare,andmuchmoreuseIoTforconnecting different equipment. IoT is completely based on data sharing and the risk of data vulnerability is also considerably increased. In order to safeguard the data, a new study withthehelpofGenericProgramming(GP)wasimplemented.Topreventtheattacks,an artificial Immune intrusion detection system (IDS) was developed. It was observed that GPattackersfocussedonthepublish-subscriptiontypeofmessages.Theperformanceof theIDSwasimprovedwiththeGPattacks[11].Asmarthealthcaresystemwasdeveloped withthehelpofambientassistedliving(AAL).TheperformanceofAALissolelydependent on the accuracy of predicting the nature of the environment and human behavior.Datacanbecollectedfromdifferentsensorspresentaroundusanditisneeded thatthesedatacollectedarefurthersentforprocessinganddrawingoutconclusionsbased on the observed data. In AAL elderly people are monitored continuously and then their changes are observed very carefully.

Not only were the changes measured from the elderly subjects but also Alzheimer's disease (AD). With the development of AAL, doctors can interact with the patient remotely and access the health status more accurately, and also can assist them without their actual presence. Moreover, it provides great relief to the patients that they are always taken care of which helps them in recovering soon [12]. Because of the massive usage of IoT in different fields in order to enhance the availability of IoT and makeitaccessibletoalmostallpartsoftheworld.ItwasdecidedtocombineideasofIoT with that of social networking due to which the Social Internet of Things (SIOT) was developed.Atrustworthyautomaticschemewasdevelopedinordertojudgetheproduct. This scheme enabled different users to judge the products and then score them accordingly. It also helped in determining the other users to choose the products wisely and then enable the product service also. Social networking along with the IoT enabled the trust factor of the products or the objects [13].

IoT handles datavery well and an almost largenumberofdata can be stored and accessedthroughIoT.ButtheissueofinterpretingthedataremainsachallengingtaskIoT. So human interference in this subject is also liable and makes the system more accurate. Two IoT-enabled devices are taken for the experimentation of understanding thedatameasuredthroughthesensorsapartfromstoringitinthecloud.Itwasconcluded that human-aided IoT systems have a higher rate of accuracy when compared to that simpleIoTstructuresforthedevelopmentofmedicalhealthcare[14].Withtheevolution ofIoT,patientscanbemonitoredremotely.Thehealthofanindividualcanbedetermined with the study of sleep postures. But exact tool to assess the sleep posture to study the sleep pattern is still a challenging task.

Anagent-Basedsimulationsystemisdevelopedalongwiththesmartbedtostudy the movements of the sleeper. An algorithm was developed to understand the sleeping postureofthesubjectonthesmartbed.Thismeasurementisdonewiththehelpofplacing the load sensors on the bed for determining the changes in the sleeping posture. The developedsystemwasgiventhenameABS-BedIoT,whichdeterminesthesleepingposture of the subject and then determines the graphical analysis of the results obtained from the measurement. States of the bed sensors are represented not only in graphical method but also using star plots, evolution charts, and visual representation. The techniqueisnotonlyfeasibleonlinebutalsooffline.Thecodeusedforthealgorithmcan be easily retrieved from the public research repository. The accuracy rate of the determination of sleep posture is increased with the help of the alternative technique for measurement. Final data processing is done with the help of Big Data and created logs for the sleeper's posture recognition. The average accuracy of the system is determined to be 98% with the help of a developed algorithm [15]. In the UK an experiment was conductedtocombinehealthcaremanagementwiththatofIoT.Thedesignwassuchthat it included continuous monitoring of the patient and necessary decisions are also implemented when needed at most. It was concluded that the developed system alone cannotbethateffectivesotomakeitmorereliableandaccurateitisimportanttointerface human experience into the system [16].

## 2.STEP-WISEIMPLEMENTATIONOFIOTARCHITECTURE

Afteradetailedstudythepatientdatabaseiscreatedandthedataarestoredin the cloud with help of IoT. Hence the implementation requires the following steps,

### 2.1 BasicTerminologiesInvolvedinWebDevelopment

The development of IoT technology involves many steps and each stage of development requires a separate set of procedures to be followed and all these methodologies are discussed.

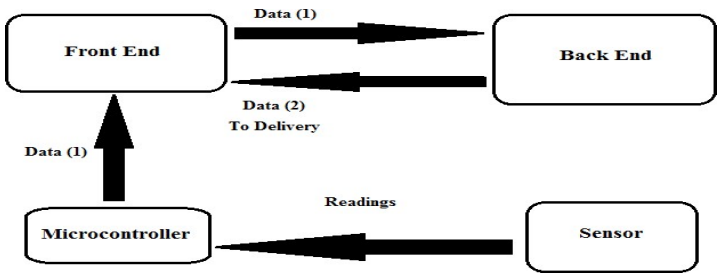


Fig2.1BlockDiagramRepresentationofIoT

CertainterminologiesareusedinIoT,whichisnecessarytobeknown.Herethe***cloud***meansthepla ceallthecreatininevalueisabouttobestored.Itisassistedbythe***frontend***and***backend***.Thefrontendmeans themonitorscreenofthePC,tablet,phone, Laptop which acts as a receiver. Coding is done to develop the front end of the server. Now, the back end refers to the storage area, which is accessed when the data is moved to the front end either automatically or manually by the user.“***PHP***”istheprogramminglanguageforWebdevelopmentwhichincludes**C**and **C**++asaprimaryelements.WiththehelpofPHP backendis connectedto thefrontend and data transfer is possible. The detailed explanation of the block diagram is shown in Fig 2.1, firstly the data received from the sensor is sent to the front end through microcontroller coding. And then the data is sent to the back end of the server. Data (1) means the creatinine value estimated by the controller which cannot be seen by the user until it is moved to the front end again from the back end of the server. Data (2) means thecreatininevaluewhich is seen by theuserfrom its stored area. It is important to note thatprogramminglanguageslike***HTML,Java,JavaScript,***and**PHP**canbeusedtocode fordatatransferfrom the backendto thefrontendwhereas thePHPtoolisusedtocode for data transfer from the front end to the back end. ***Bootstrap, CSS*** is the other programming languages that are used to improve the presentation of the front end and make it more attractive to the user.

### 2.2TransmissionofcreatininevaluetoServer Manually

Forsendingthedatatotheservermanuallyitisessentialtoinstalltwoapplication software named ***Notepade++*** and ***Xampp.*** These two applications are necessary to develop a local server. Firstly, PCs in which these applications are installed are made to work as a local server and the data is sent manually. From this trial version, gradually code can be extended and then allow the microcontroller to be interfaced with IoT and

accessaprivateserverthroughtheinternet.Itisoneofthemostimportantcriteriatosave any code with .php and .html formats. One of the most advantageous features of these applications is that it helps in detecting the error in the code before running it. There are many other applications available for web development by Xampp and Notepade++ is considered to be a handy tool.

Xampp is an application specially designed for testing the code in a local server. Moreover, an internet connection is not required after this application is being installed. ForatrialversionofIoT,theserverisnothingbutthePC.Here,thedataenteredmanuallyis sent to the laptop via the above-mentioned applications. Fig 2.2 shows the Xamp++ applicationafterbeinginstalledonthePC.Thenthefurtherprocessisdonewiththehelp of the setup wizard.


Fig 2.2SetupWizardWindowofXamppFig2.3Windowfor choosingLocalServer

Fig2.3showshowthelocalserverischosenoncewhentheXamppapplicationis installed.Afterpressingthe“Next”optionfromthesetupwindowitasksforlocalserver selection.Thecodeswrittenforthedatatransferinthelocalserver arewritteninPHPor HTMLandthenfurtherthiscodeissavedinthehtdocsofXamppfromthe localdiskC. Nowwiththehelpofgooglechromewithoutactuallyconnectingtotheinternet,typethe linkhttp://127.0.0.1/dashboard/.Assoonasthelinkissearcheddashboardofthe Xampp is popped in the window of the PC as shown in Fig 2.4.

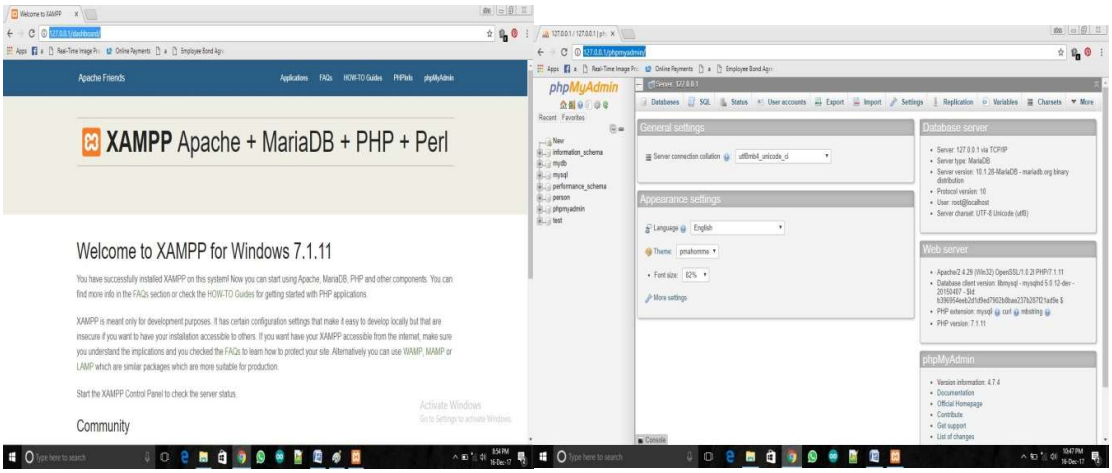


Fig2.4DashboardofXamppinthePCFig 2.5“phpMyAdmin”WindowinXampp

After which phpMyAdmin page is opened. Another alternative is provided to reachthephpMyAdminpagewiththehelpofthe linkhttp://127.0.0.1/phpmysdmin/and a new database is created as shown in Fig 4.5. The appearance of the database can be changed on this page with the help of the appearance setting.

MySQLisknownastheStructuredQueryProgrammingforimplementationofthetable . “Query”basicallymeansfunctionorelsecanbetermedasacommand.MySQLlanguage uses operation commands such as create, insert, extract, order by, join, etc. As shown in Fig2.6newdatabasecanbecreatedwiththehelpofanewoptionfromthephpMyAdmin window. “Sensor” is the name given to the new database such as “Creatinine Data” can be created as the name for the new database which is clearly shown in Fig 2.7. After finalizing the name of the database further “Create” option is clicked.

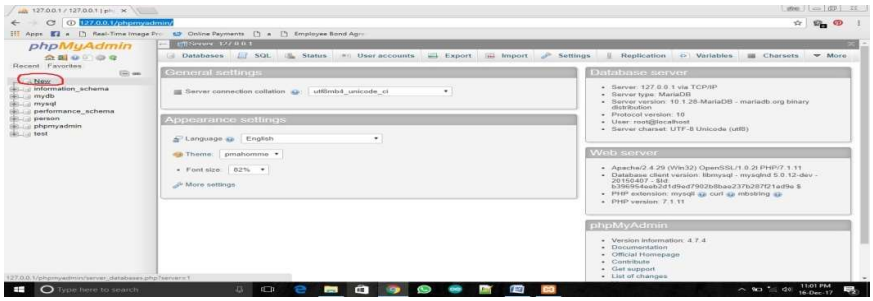


Fig2.6Selecting“New”fordatabase

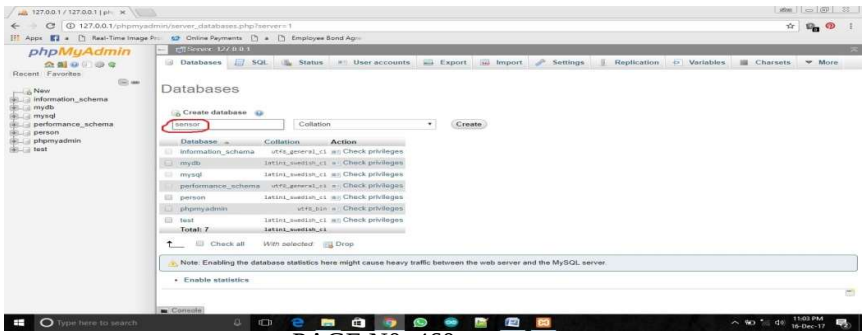

Fig2.7Namingthecreateddatabase

From Fig 2.8 it can be seen that the new database “Sensors” is created under the new option. This indicates that the new database was created successfully. Understructure, the table “<name>” is selected. It is important to note that the name of the table and the column of the table is needed, not the rows.

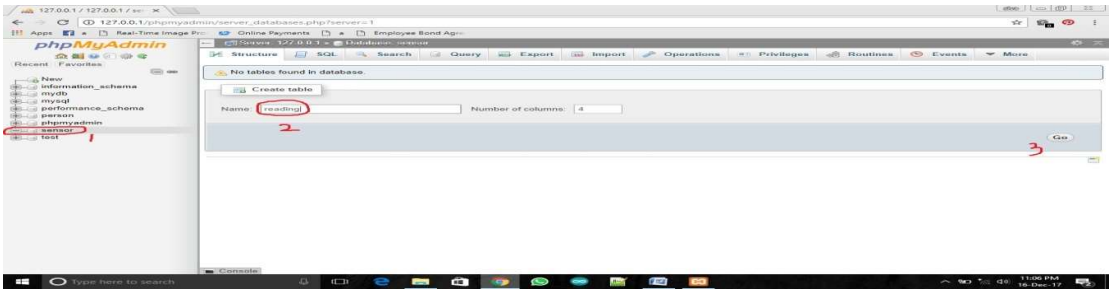

Fig2.8Creating thelayout ofatablefordata storage

Thetitleof thetable is chosen as “readings” as thecreatininevalueofthe datais about to be stored under the table. After which numbers of columns are selected this is particularly4aspertheneedoftheuser.Afterfinishingthetablelayout“GO”optioncan be clicked to create the table which is shown in Fig 2.9. All together four columns are introduced in the table which are Serial Number, Patient ID, Time and date, creatinine value, and State of the Subject under the name content of the table.

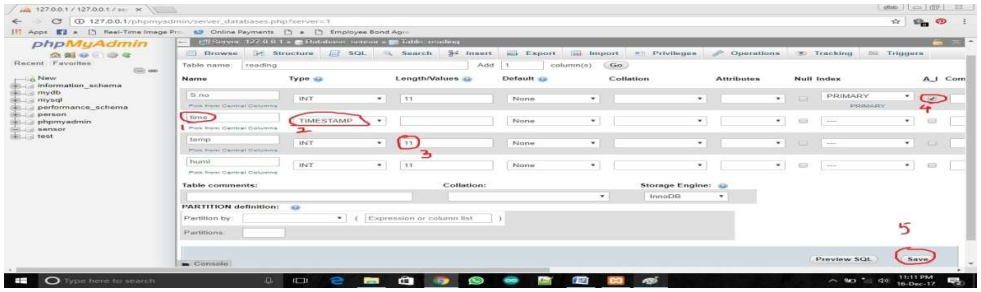

Fig 2.9Creatingthecontentsinsidethetable

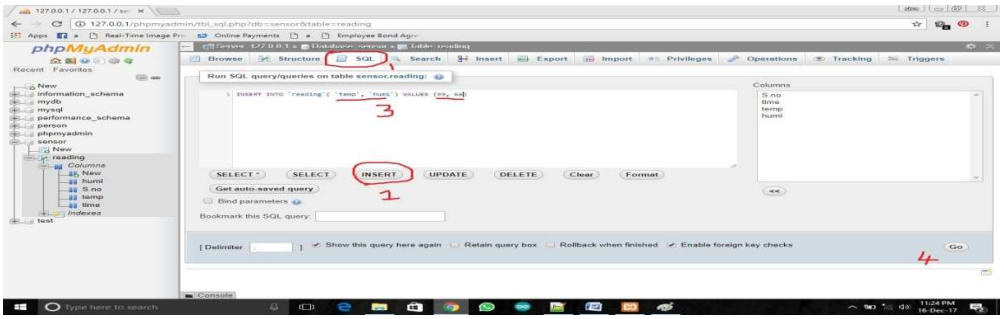

Fig2.10 InsertionofDataManually

FromthephpMyAdmin window, theSQLoption next to thestructureis selected to enter the table manually as shown in Fig 2.10. “INSERT INTO” is the code used for insertingthedata. After filling in the data INSERT option is selected to upload the data into the table. From Fig 2.11 it can be noted that the values which are uploaded getupdated.Herethecreatininehighandcreatininelowvaluesareuploadedas99and66.Soistheproced ureforcreatininedataentry.

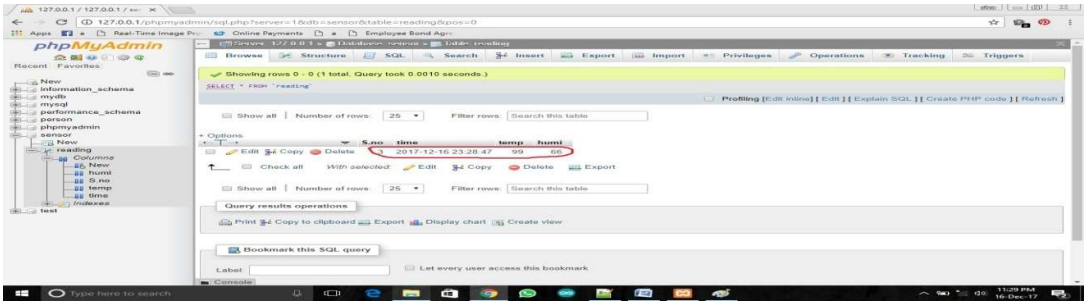

Fig2.11FinalViewoftheTablewithDataEntered Manually

### 2.1.1 UploadingDataAutomaticallyViaControllerandWi-FiModule.

The above-mentioned procedure is done in the Back End. To make it viable for microcontroller update it is essential to work under the front end and separately code it withthehelpofanotherapplicationcallednotepad++.From Fig2.12itcanbenotedthat the developed code is stored in htdcos of Xampp folder from the C drive.


Fig2.12DatabasecreatedusingFrontEnd Coding

### 2.1.2CreatingandTransferringDataTotheWeb Page

Nowaseparateweb pageiscreatedintheserver andanew domain name is given. The user has to register in the link www.awardspace.com which is one of the important websites to create a new domain. The webpage opens a new window in which the name of the domain is chosen which is clearly shown in Fig 2.13.

Fig2.13NewWebsiteforDomainCreation

From Fig 2.14 it can be seen that the name of the domain is chosen. It is important to choose a unique domain name that can be used permanently. So, a random name under the “name” is given and then the domain is checked.


Fig2.14CheckingDomainName

Fig 2.15 shows the image of the screen when the domain “name” is chosen uniquely. After the authentication of the domain “name” the registration process is successfully completed.

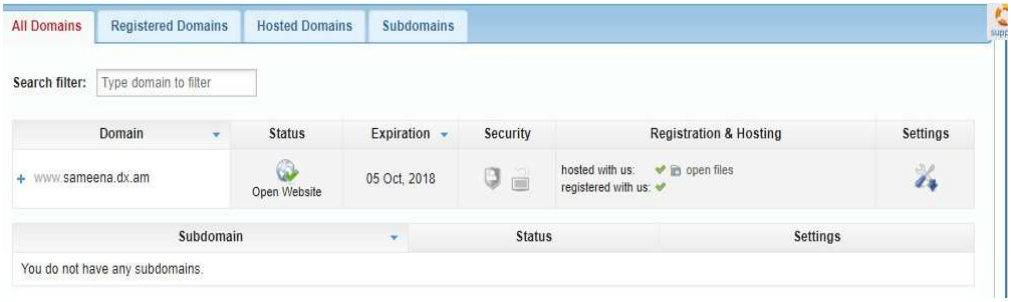


Fig2.15Authentication ofDomainName

Inordertocreatethedatabaseaftervalidatingthedomainnameclickonthe domainmanagerfromFig2.13toenablethedatabasewhichisclearlyshowninFig2.16.

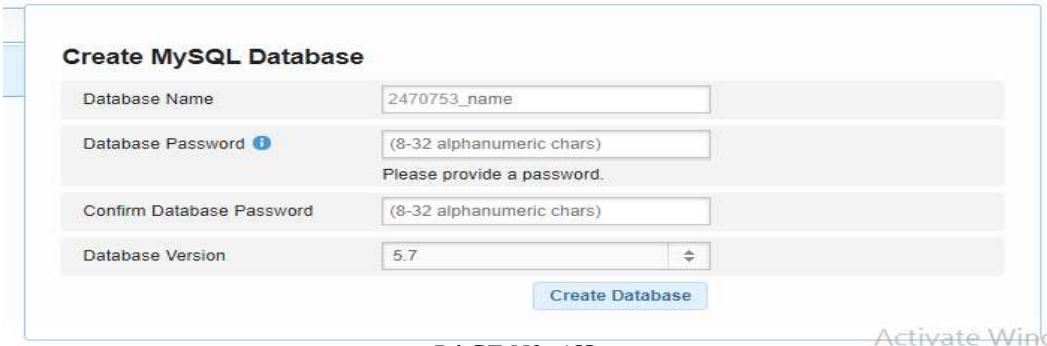

Fig2.16MySQLDatabaseCreation

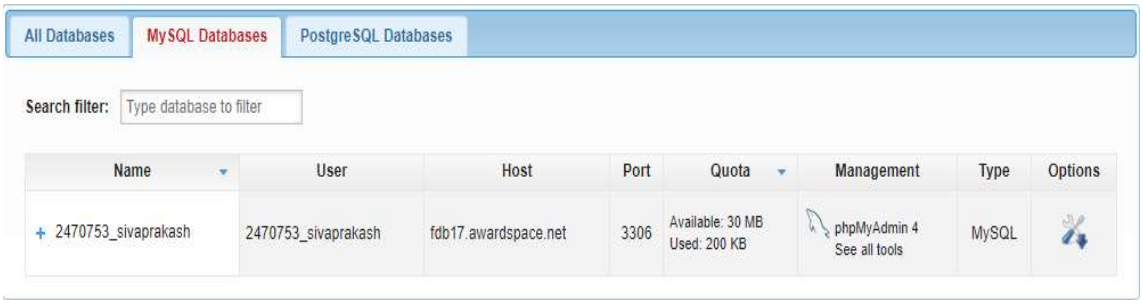


Fig2.17Authentication ofthecreated database

Successfully the database is created which is clearly shown in Fig 2.17. Here to increase the privacy of the data transferred into the web page, a special password is also given.

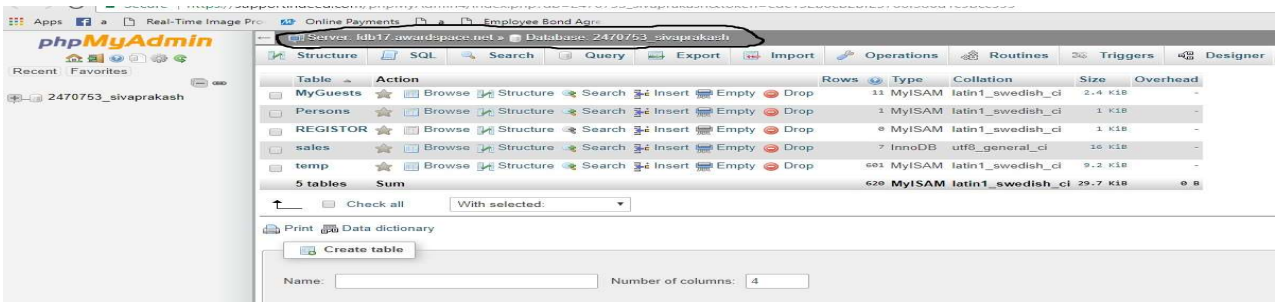


Fig2.17NewlyCreatedServerand Database

FromFig2.18itcanbeseenthattheserver'sname,databasename,thepassword is shown which represents the state of the web page that is newly created.

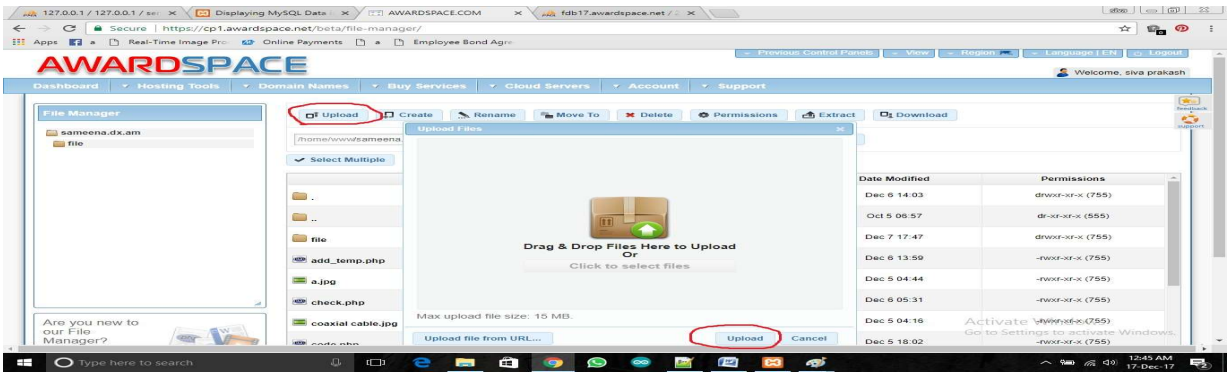


Fig2.18uploadingtheFront-EndCodeIntoAwardspace

FromFig2.14filemanagerischosenforuploadingthecode.Finally,thecodeof the controller sending the data of creatinine automatically which is in the PHP format is uploaded here which can be seen from Fig 2.20.

## 2.2 RESULTANDDISCUSSION


| Patient ID | Semen Creatinine Level (µmol/L ) | Salivary Creatinine Level (µmol/L ) | Time_Date |
|---|---|---|---|
| 1299570091 | 92 | 108 | 10:55_12-08-19 |
| 1299570092 | 118 | 92 | 11:22_12-08-19 |
| 1299570093 | 290 | 123 | 12:34_12-08-19 |
| 1299570094 | 122 | 120 | 13:09_12-08-19 |
| 1299570095 | 109 | 130 | 14:30_12-08-19 |
| 1299570096 | 89 | 110 | 15:45_12-08-19 |
| 1299570097 | 156 | 187 | 16:25_12-08-19 |

Fig2.19FinalViewoftheTableonthe Webpage

Fig2.19showsthefinalviewofthetablecreatedwiththecreatininelowandcreatinineHighvaluesareshowni nthisimage.ThisishowthetableiscreatedforS.No, creatinine value, time, date, patient ID, and state of the subject are determined and then filled inside the table.

## 2.3 CONCLUSION

Theanalysisofthecreatininevalueinallemotional states helps in validating the risk factors of the subject and helps in predicting any abnormalities much before the onset of any dangerous disease.Physicians or caretakers may not be present with the patient all the time. So, itbecomesnecessarytomonitorthehealthstatusofthepatientregularlywithoutany interruptions with help of IoT.Moreover,it is inevitable to automaticallysend the data to the serverwithout the helpofthemicrocontroller.Itisalsonecessarytounderstandthesupportingapplications fordevelopingtheIoT.Apartfromthatthedatafromthecreatinineisprocessedandthen these values are changed in the URL itself which is aided by the front end Xampp code. Changing the contents of the URL makes changes in the values that are entered in thetable.Withthehelpoftheauto-incrementfeature,thetablecreationisautomaticallydone. Oncethedataisuploadedthentheback-endcodeisexecutedandthedataor updatedtableissenttothefrontend.Nowfromtheuserside,thetabularformatof creatinine value with the state representation is depicted and then further analysis of the datacanbedoneontheMATLAB.Herewithhelpofthedomainnameandthepassword user can access the data from any part of the world and at any time. In order to maintain theprivacyofthedatabeinguploadedtotheserver,thepasswordisgeneratedalongwith thecreationofthedomain.Inthisway,theprivacyofthedataisrestoredandcyberthreatscanbeminimizedto greatextentby makingitviable toanauthenticated user.

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