Cloud based E-Prescription management system for healthcare services using IoT devices

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Management of data plays an important role in the healthcare systems and has impacts on the performance of the software applications used. Current healthcare systems don't utilize the facilities provided by the latest equipment for their stakeholders to interact with the system. The flexibility for pharmacists to interact with the current systems is not as efficient as it should be. Apart from this, we propose a system based on android and a web application by which a doctor has the ability to prescribe patients through an android application using stylus pen and other users such as patients, receptionists, pharmacists and admins interact with the system via their web accessibility. The proposed system is based on integration of Internet of Things and cloud computing technologies using Arduino and E-Health sensors. The users utilize the registered IoT devices which facilitate the healthcare stakeholders, making the system efficient, user-friendly and less error prone. Overall, we propose a better solution of managing the healthcare data as well as provide an easy way to interact with the system.

Keywords—Healthcare, E-prescription, Internet of Things, Cloud of Things, Arduino

I. INTRODUCTION

Electronic prescription is an important policy to improve the healthcare industry. The electronic prescriptions allow the healthcare systems to be more predictive and acknowledgeable about the patient. As we know that there are a lot of patients who follow up the same procedure to get the results of a test or the state of the patient's health.

Cross-border prescriptions are only possible if the prescriptions are made available online to the registered healthcare systems and to record each and every detail of the patient history such as prescriptions, medicine intake, states of the patient over the period of time, billing and information. Centralizing all of these inputs taken from the patient will reduce the time taken by the patient to be cured as well as it will reduce the prices of medication. The chances of curing the patient will be higher. The factor of accountability of specialists will increase which will impose a friendly ecosystem for the customer/patient.

Another aspect of benefit from this kind of systems is of pharmaceutical industry. This will allow the pharmacists to validate the prescriptions, allowing the proper check and balance of the intake dosage of medicine by the patient through the system.

Pharmacies are also be able to save their data in a computer-based system that is not a file-based system which allows the system to be flexible. It allows makes the process of management a lot easier and reduces the expense of managing the data of inventories.

Saving the data of healthcare systems this way reduces the chance of data loss, in some cases. Locating the particular patient or employee data is a lot easier if the electronic health records are achieved.

One problem in this area is maintaining the integrity, security and confidentiality of patient's data. There are different systems built to address and solve this issue. The employees and the patients will have to be a little knowledgeable to operate the advance-system of healthcare.

Different intelligent applications could be proposed in this field of ubiquitous-healthcare. The applications could be based on the inventory system of pharmacies, token system for receptionists, predictions about the patient on the doctor's dashboard, training applications for the fresh graduates to be trained in the healthcare system, alert notifications to the insurance companies for the investigation of such cases based on medical-history. Overall, the system will have humungous benefits through the proper management and usage of healthcare data, electronically.

The systems based on healthcare provide great flexibility to the administrative operators as well. The electronic prescriptions could be encrypted end-to-end to secure the prescription as well as to ensure the integrity of the user data too. The interaction of doctors with the applications is quite easy when it comes to the prescriptions.

The latest equipment used in the healthcare systems for treating the patient could be integrated with the system's central data repository. From those repositories of data, applications could predict or suggest some diagnostics, medicines, patient's health-state to the doctor, via exposed API interfaces to the data. This way the secrecy and privacy could also be tackled in the form of electronic agreements made between the healthcare institutions and federal/government institutions.

This mechanism allows the healthcare systems to evolve in dynamic directions which needs to be controlled by proper legislations and regulations. One way of such approach is through he blockchain networks, which is currently the hottest topic in IT industry.

Interoperability is the key to integrate and provide a flexible healthcare system. Using such mechanisms such as APIs, blockchain networks, IoT devices and much more of 5G network services will evolve the healthcare sector in dynamic and versatile environments.

Usage of IoT devices in healthcare will bring innovation with it and provide efficient and less error prone interactions to the healthcare stakeholders. The intelligent devices will be able to provide faster processing for the repetitive tasks that the healthcare employees had to manually before.

Rest of the paper is organized as follows. Section 2 represents the related literature and work. Section 3 and 4 highlights the system details and experimental environment. Section 5 briefly provides the concluding remarks.

II. LITERATURE REVIEW

Internet of Things (IoT) is getting wide attention by researchers and engineers. With the rapid development in medical and computing, the healthcare systems has gained interest from both the academics and industry [1]. IoT is the network of physical devices communicating with each other via Internet. IoT is growing adoption in many aspects of our daily life. IoT is being integrated in banking, hospitals, education with the help of cloud computing technology. IoT and cloud computing give rise to smart homes [2], smart hospitals, smart factories. One such use of IoT and cloud computing is in health care industry to provide services to the doctors, patients, staff, and pharmacists. IoT in healthcare industry make hospitals more efficient and provide physicians with the relevant patient data that can be used to decide and recommend medicine or surgery. The use of automation system in hospitals and clinics is to provide an efficient working environment for healthcare professionals [3].

Healthcare is such a vast ecosystem [4], that the applications of the IoT in healthcare seem to be endless. Remote monitoring of the patient and personal healthcare by using smart sensors and medical based IoT devices [5]. IoT is also used for pharmaceutical industry, Real Time Health Systems (RTHS), healthcare insurance, smart pill dispensers. There have many been many efforts in developing health monitoring systems. Wearable devices play a vital role in the wireless health monitoring systems [6]. The healthcare industry has adopted these devices because of low operational cost and improved efficiency. These devices consume less power and memory for processing. Wearable devices are used to find the heart rate, blood pressure, blood glucose, and much more of the patient. One of the advantages of wearable devices is that they offer individuals with the data they require to gain much better control over their health outcomes. These devices generate huge amount of data. As these devices processes low power and memory storage, there is need of cloud computing technology to enhance the capabilities of the wearable devices.

Delivering high quality healthcare services [7] to the patients is one of the challenges for hospitals throughout the world. The primary goal of the hospitals is to take care of its patients. Previously, due to lack of technology, the processes are delayed and the patient could not be treated properly on time. Recording patient data manually is time consuming and sometime the specialist is not currently on site. To avoid these problems, smart hospitals aim to provide solutions by integrating latest communication technologies.

Smart healthcare solutions provide both patients and doctors with interactive and customized healthcare services such as online access to medical records, disease diagnosis, and treatment of patients [8]. With the help of cloud IoT and cloud computing technologies, smart healthcare services can be achieved. Nowadays there are many low-cost sensors that are capable of monitoring patient's health such as blood pressure, blood glucose, electrocardiography (ECG), heartbeat. These sensors can be utilized to check the patient's health from anywhere and data can be sent to the doctor online via Internet for decision and recommendation. This can lead to immediate action and speedy recovery of the patient.

Nowadays Open-source Electronic Health Record (EHR) systems have gained importance. EHR is an electronic version of a patient's medical record. EHRs has improved the relationship between patients and clinicians. The data, and the timeliness and availability of it, will enable providers to make better decisions and provide better care. There are many advantages of EHR such as it reduces the incidence of medical error by improving the accuracy of a medical record, health information is available online, reducing delays in treatment, reducing duplication of tests. The benefit of EHR is that the patient's medical history is stored online and can be used for future. Doctors can fetch the history of the patient according to requirement and recommend medicine or operation [9].

EHR systems integrated with IoT can provide broad personalized healthcare solutions such as connect wearable devices to the cloud. Collect and analyze patient's data in real time. It can help monitor vital health indicators. It can visualize the data with the help of charts and diagrams for the doctor. With IoT, emergency notifications can be sent to the doctor. IoT based medical devices help patients for speedy recovery [10].

As low-cost sensor possesses less power and memory so it is difficult to deal with huge amount of data. Cloud computing plays vital role in the storage and processing of data. There are different clouds that provide online services such as Google cloud, Amazon cloud, IBM cloud. The integration of IoT and cloud is referred as Cloud of Things (CoT). CoT collects the decentralized sensor data of IoT devices in real time and evaluates and process the data. The data on the cloud is secured and easily accessible remotely.

There are different IoT devices available in the market such as Arduino and Raspberry Pi [11]. Arduino is a small microcontroller motherboard whereas Raspberry pi is small computer used for general purpose, usually with the Linux operating system, and the ability to run multiple programs. Arduino board has its own programming language known as Arduino similar to C language. Different sensors and actuators can be attached with Arduino or Raspberry pi for specific tasks. E-health v2.0 consists of 16 different sensors related to healthcare. These sensors are used to monitor the patient's health. E-health can be used with Arduino or Raspberry Pi.

There are different protocols used for IoT communication such as Constrained Application Protocol (CoAP), Message Queuing Telemetry Transport (MQTT) protocol, Advanced Message Queuing Protocol (AMQP) [12]. CoAP is mainly restricted for small gadgets. Just like Hyper Text Transfer Protocol (HTTP), it also uses the restful architecture. MQTT is a lightweight protocol which is based on publish/subscribe technique. There are two types MQTT client and MQTT broker. The client publishes messages to the broker against a unique topic. The broker distributes the message and publish to the corresponding client. The corresponding client is subscribed to the unique topic. AMQP is an application layer protocol, specifically designed for supporting messaging applications and communication patterns [13].

Smart hospital management system help increase patient participation and satisfaction, improve healthcare decisions [14], streamline the work processes to impart value-based healthcare, automation increases productivity in administration tasks, and ensures safe and effective use of medicines [15].

III. SYSTEM DETAILS

This section contains the details of overall proposed system. First, we discuss about the user interactions with the system. Then we present the sequence diagrams, data flow diagrams. We also discuss the uniqueness of our proposed system.

Another use case is that the patient can take an offline appointment from the doctor. The receptionist can call the patients in a specific sequence, generated by the system. So, the point here is that when the doctor prescribes one patient, he has the option to call the next patient and he can retrieve the historical-information of the patient instantly on the android tablet or a smartphone device. The doctor can prescribe the patient via checking him up via the IoT devices registered in the clinic e.g. the blood-pressure IoT device, temperature device. This process makes sure the automation of data inputs into the prescription instantly when the doctor uses the device with the patient. This reduces the effort for a doctor to focus more on the patient's health rather than consuming his/her time on entering the patient-data manually.

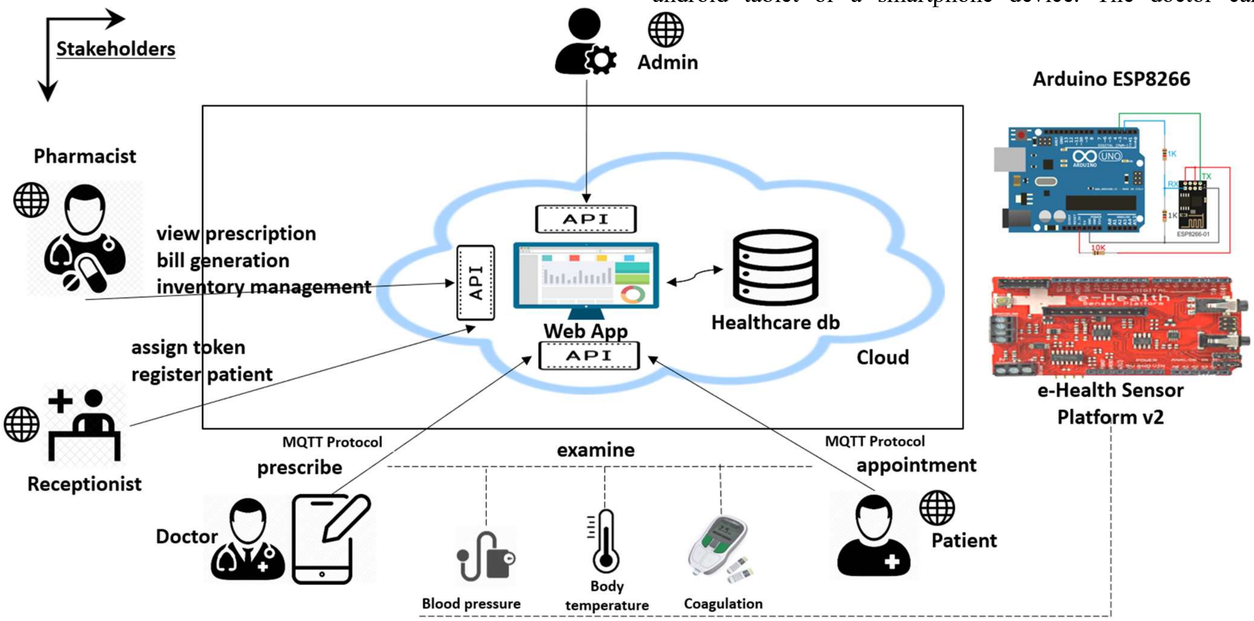

Fig. 1. Overall System Overview of Healthcare System with IoT devices

Fig. 1. Represents the overall system overview. The system includes 5 types of users which are admin, doctors, pharmacists, receptionists and patients. Doctor interacts with the android interface provided in the form of an android application. Four of the remaining users interact with the system using our web-application. As each of the users has its own role in the different processes to be followed in the daily routine of healthcare systems, we define each of these activities in the form of activity, sequence, data-flow diagrams.

All of the stakeholder requests communicate with the system either through a web-interface or a smartphone-interface. Also, the streaming analytics for the IoT devices as well. The point that needs to be highlighted here is that the all requests are passed through well-defined API interfaces. These requests could either be the GET or POST requests. The backend, database and IoT-platform are deployed onto Amazon cloud.

Before going into much details, I would like to highlight some of the use case that a patient can perform. Patient needs to be registered into the system with the help of a receptionist. Patient has the option to access information related to prescriptions and billing. He can get appointed online and has to reconfirm about the patient's appointment with the doctor. For that purpose, patient needs to visit the receptionist so that he/she may generate a token through the system via a registered IoT token-generation device. This device is registered onto the IoT platform used on the Amazon cloud services. The service receives a request to generate a token via communicating through MQTT protocol. The streaming analytics is responsible to stream the data to our hospital management database, which then generates a token receipt for the patient via an authenticated channel.

Once, the prescription is done. It is submitted to the system via API exposed interface which are responsible to store patient-data in the form of a prescription. The patient, as usual needs to visit the pharmacy and get the treatment-dose from any of the pharmacy inside the healthcare systems. If the pharmacy does not have the dose for that patient or in any other case, it would be permissible to print the prescription. This process saves the cost of paper and reduces the chances of getting the prescription stored on a central repository. Which could then be streamed to other government healthcare systems. This hierarchy allows the patient to get treatment from any of the healthcare systems and the doctor would be able to fetch the previous information of the patient.

The pharmacy has the facility to generate bills for the patients as well as the hospitals for the imported drugs. Managing all of the information on cloud allows the government to downstream the rules and regulation instantly on the healthcare industrial systems. The pharmacy has two types of inventories. One is for the raw-material imported for the hospital so that the experts/scientists could make the inhouse medicines. Once the raw-material is store into the system. It can be consumed in the making of medicine which makes the admin to perform an operation of converting the number of raw-material used to create a final product.

Admin being the most important of healthcare systems, is responsible to maintain and manage the users and also if sometimes, if any user is facing any problems during the online/offline process then the admin can sort out the problem. As the admin has all the rights to perform all CRUD operations. Admin features include resetting information related to the user, delete users, block users, preview and manage all of the information of any users.

As an example, it can be seen in the Fig. 2 that a doctor accesses the web application data using his smartphone application by logging in first. If the access is granted, a e-prescription request is made and the relevant IoT device which needs to assist the doctor while prescribing the patient is used. Further on, this IoT device in the Fig. 2 can be seen communicating with the web-server via MQTT protocol. As the data is pushed onto the server, both the patient and pharmacist are notified if the prescription is complete and an acknowledgement is sent back to the doctor application to ensure the application's responsiveness.

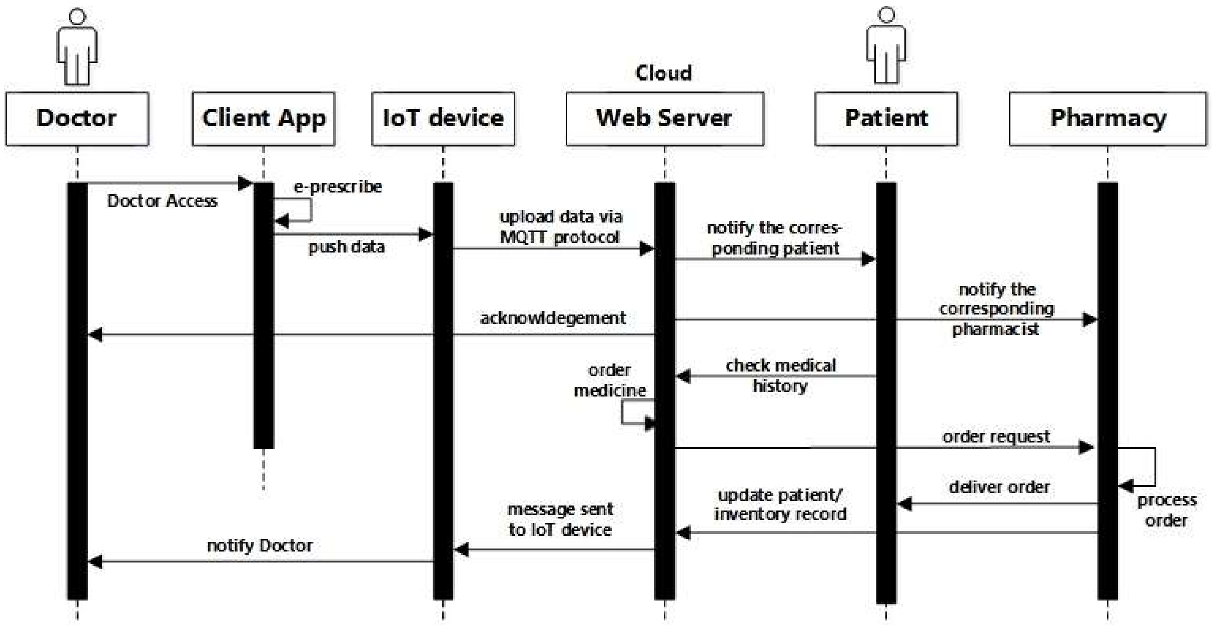

Fig. 2. Sequence Diagram where doctor prescribes a patient

The above Fig. 2 shows the sequence of steps that a doctor takes to get analytics of the patient's relevant information during a prescription is being made for the patient. In our case, we used blood-pressure, body-temperature etc, configured with the IoT platform. Suppose, a doctor has a patient in his room for which he needs his blood pressure records. This system will allow the doctor to use the machine to check blood-pressure. The readings from this IoT based blood pressure device will be published to the IoT Cloud repository, automatically through a proper and secure channel. The readings are instantly streamed over to the database of our application. This way, the doctor gets the readings of patient automatically into the system. It also supports the system to be less error-prone. As sometimes a doctor can make a mistake while entering the data manually.

The IoT device needs to be registered, already on the IoT platform whether it be any of the cloud platforms such as Amazon, Window Azure, Google etc. In our case's scenario, we are using Amazon as a cloud which provides these services. The web application is also deployed on the same cloud but is independent from the IoT platform system.

Now, as the data is being published or synced constantly when the machine/IoT device is inactive mode. All of the data that is related to this data needs to be streamed to the healthcare database via the exposed APIs. It can be seen in the above Fig. 2. While the data has been streamed to the database successfully. Doctor is able to see instant results, afterwards. While all of this process, the doctor does not need to enter the data manually and only needs to turn on the IoT device that needs to publish patient's relevant data.

The e-prescription has been implemented in many ways as the image stored (i.e. e-prescription) via doctor's android application is online and accessible. The pharmaceutical information such as the storage of medical records in the form of prescriptions as well as the inventory is also an e-prescription. The e-bills generated in the form of ingredients are also shown to the end user as well as the doctor to get more insights of the historical medical dose used by the patient. The conversion of internal raw material for the inventory is also an innovative step that could allow the instant medical provision in case of urgency. This allows the faster and immediate delivery of medicine to the healthcare system, without the cost of goods-transport. Conversion of all these e-prescription data or information collectively will bring responsive healthcare systems which will have immediate effect on the treatment process of the patient as the doctor will have more insights in the form of a digital prescription.

Further on, patient can request a medical checkup history in which he can place an order of medicine to the pharmacy which is first requested to the web server and then the pharmacist delivers the order and takes necessary steps to update the system state in terms of patient's medical record as well as the management of the inventory system of the healthcare system. The message or response is sent back to the

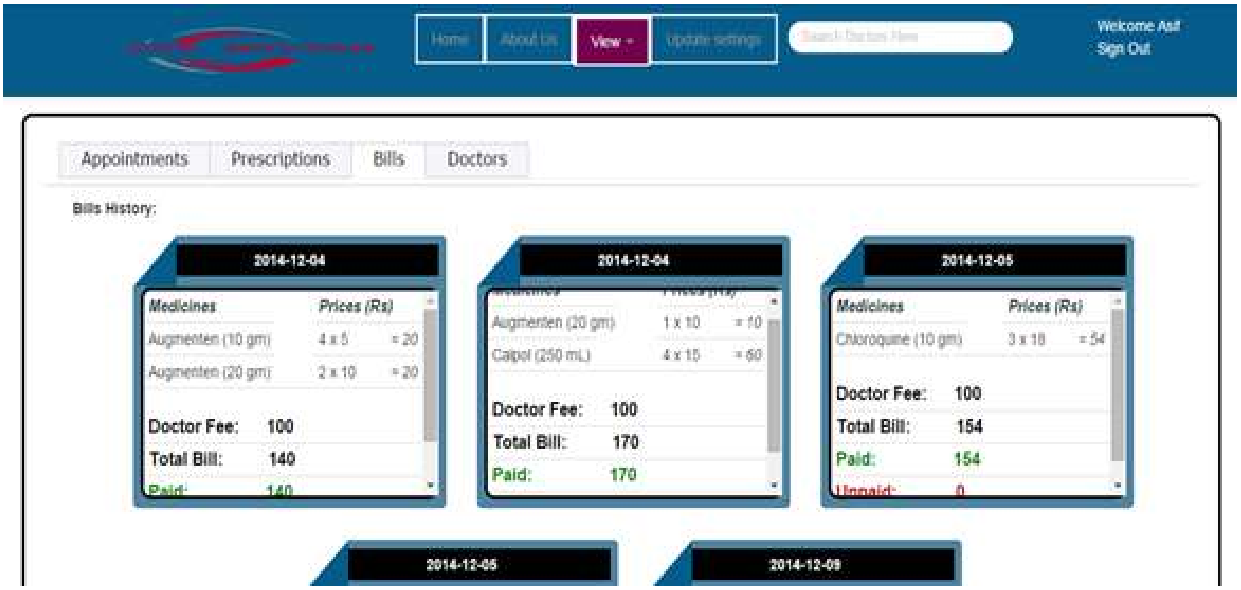

Fig. 3. Pharmacist's web-interface, showing the generated e-bills.

IoT device for further actions. Which further notifies the doctor about the complete process completion.

Fig. 3 shows the electronic bills generated via the web-portal provided to each of the different type of user. It includes the information such as medicine price as well as the doctor fee, discounted prices etc. The tracking of unpaid bill si also provided to the pharmacist and the patient can pay his bills later if the doctor has flagged the patient by turning on the flag in special cases. In the case of the patient does not pay the bill for a long time, a fine is imposed onto the patient along with the doctor who was the guarantor of that specific patient for that specific e-bill/e-prescription.

IV. EXPERIMENTS

Current section contains the steps and requirements needed to setup the experimental testbed. After it we present the evaluation section that evaluates out system in performance due to the usage of IoT enabled devices in the healthcare systems.

A. Setup

The requirements for setting up the IoT based Healthcare system are given in Table. 1:

TABLE I. HARDWARE AND SOFTWARE REQUIRED FOR TESTBED

Component		Description
Hardware	Arduino	Arduino ESP8266 board is used in the experiment. Arduino is a small micro-controller.
	E-health Sensor	E-health V2.0 is used in the experiment. It consists of 16 sensors to monitor blood pressure, blood glucose, ECG, heart-beat etc.
Web Application	Backend	PHP
	Frontend	HTML, CSS, JS. These were used to design the frontend part of the application
	Web Server	WAMP (Windows Apache MySQL PHP). This opensource web-server application was used to deploy the web application and make it accessible online
	Database	MySQL, database used for storing the data of healthcare system
	Tools	Android Studio, PuTTY, WebStorm, Sublime Text 3
Android Application	Backend/ Frontend	Java language used for the development of frontend activities and backend scripts were used (which were written in PHP) to fetch real-time data from the healthcare system.
Protocols		HTTP, SSH, MQTT
Cloud	Amazon	Elastic Compute Cloud (EC2) is used to deploy the proposed system.

We have three parts in our system. For the web application, we require a web-server (WAMP) installed on a server or a machine that is accessible on a local-network environment. We also require the database (MySQL, part of WAMP) to be configured with it. The languages used in order to develop the web-application are PHP, html, CSS, JavaScript etc. The plugins or libraries we used were jQuery, bootstrap etc.

For the smartphone application, we developed an android as interface to the doctor through which he/she could use the stylus pen to prescribe the patient. We used Java as a language for the development of this application.

Third part is related to the IoT platform, in which we have registered IoT devices on the cloud (Amazon). The IoT devices that are usable with our system are token-generator, blood-pressure and body-temperature devices. We can further enhance our system to increase performance of the hospital system to achieve the goals of efficiency, user-friendliness and less-error-proneness.

The physical view of the Arduino setup with the sensor can be seen in Fig. 4, which is registered on the IoT platform and is publishing the patient's data on the cloud where the streaming analytics service is streaming it into the healthcare center's database. Which is then ready to be used by the doctor on his android smartphone-based application.

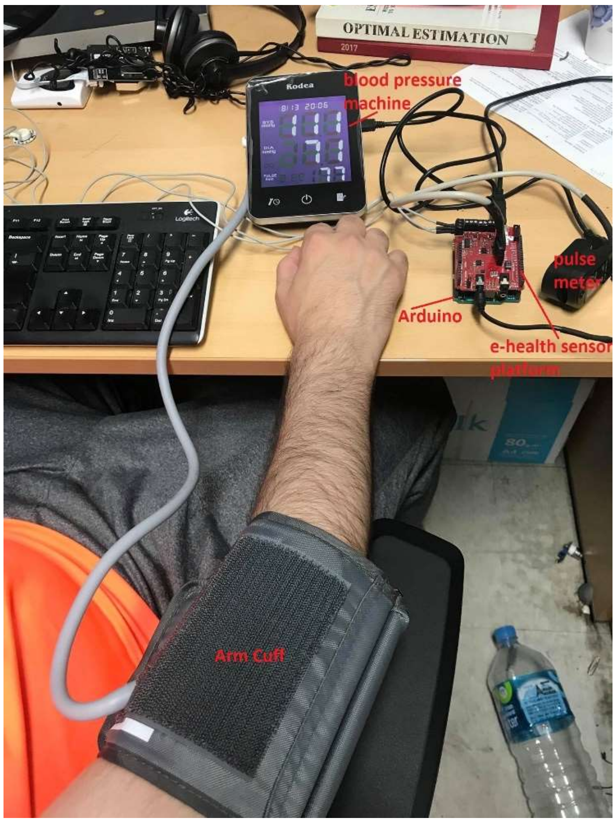

Fig. 4. Arduino setup with blood pressure sensor device.

We performed several tests for publishing the blood pressure readings to the server and observed the response time in measures to check the performance of the system. Moving onto the next section, we plan

B. Evaluation

This section covers the evaluation of proposed system. In Fig. 5, we can see response times for e-prescription system where the doctor prescribes the patients. The unit we use for presenting the statistics of response time is millisecond. The minimum value of the response time for our system is about 800 milliseconds whereas the maximum response time is 1,400 milliseconds. This figure shows the result of 100 e-prescriptions.

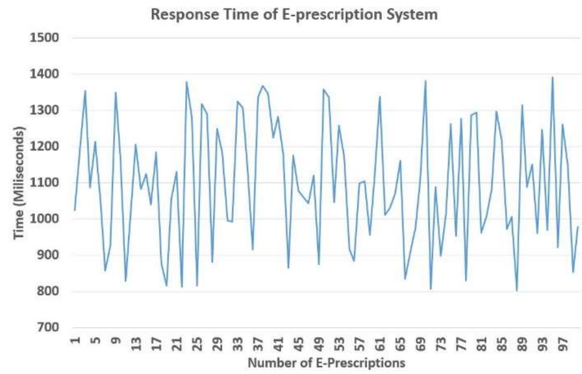

Fig. 5. Response time of e-prescription management system.

Fig. 6 shows the statistics for a specific patient. The data includes body-temperature in *Celsius*, heart-rate in beats-per-minute and blood-pressure in millimeter of mercury.

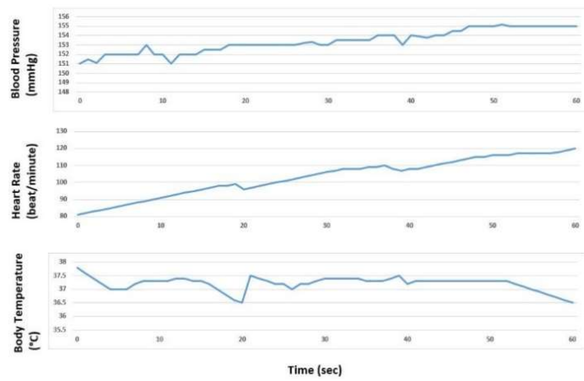

Fig. 6. Analysis of patient's medical statistics

V. CONCLUSION AND FUTURE WORK

Although healthcare systems have been improved but a lot of systems still use the process of scanning the prescriptions manually and convert them into e-prescriptions. We've made this possible by letting the doctor prescribe through an android application either on a tablet/smartphone. Another accomplishment made in our system is the usage of IoT healthcare devices which are authenticated and stream and fetch the healthcare data through proper licensed and secure channels. The performance of system has been improved with the usage of these IoT devices in terms of response-times as well as automation. This provides an easier way to the users to interact with the system smartly. We evaluated our system which provides a direction to the automation and possibilities inside the healthcare industry via the use of multiple IoT devices.

In future, we extend this work by introducing artificial intelligence in the proposed system. If the doctor is not available on site, the patient can receive e-prescription based on previous medical history in case of emergency. This can be provided as a first aid treatment to the patients.

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