mVitals - An Intelligent Edge Computing Based Wireless Mobile Healthcare System

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Evaluation

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Abstract

Internet of Things (IoT) made it possible to interconnect millions or billions of different “Things” to create huge networks. IoT based applications include but not limited to smart homes, automated parking systems, fitness bands and health monitoring systems, etc. IoT made it possible to build autonomous and effective real-time health care monitoring systems. It allows effective and flexible real-time health care monitoring systems, equipped with sensors that collect the patient’s data regarding vital signs and reduce human error. The existing systems use cloud computing technology where the collected data is stored, processed and analysed on cloud servers. As the human population has been increasing exponentially, the public healthcare sector is focusing on advanced wearable devices rather than traditional monitoring systems. Due to a lack of continuous monitoring, many patients have been suffering in hospitals as well as in homes. To overcome this problem, technical experts are discovering new and viable approaches based on various technologies e.g. cloud, edge and fog computing. The proposed intelligent system i.e. mVitals, targets such patients who require real-time healthcare monitoring. It will provide an advanced wearable system, based on edge computing. The system will be highly portable and easy to use. The key objective of mVitals is to monitor the patients’ vital signs such as heart rate, electrocardiogram (ECG), body temperature, etc. in real-time. The communication of the system will be based on wireless technology i.e. Bluetooth, so the patient wearing it will not feel tangled with wires. mVitals will be designed using Arduino Nano and various sensors such as ECG Module, heart rate, body temperature, blood pressure and breathing rate sensor. The patient’s data will be acquired via sensors and transferred to an edge server to reduce latency and bandwidth utilization. Edge server i.e. mobile phone, will transfer the real-time data to the AI server. AI server will apply machine learning algorithms on acquired data for noise reduction, analytics, predictions and alert generation. Medical history and reports of the patients will be stored in a real-time database which will further help doctors to assess the patient’s condition and suggest treatment plans based on machine learning. Healthcare is not only the most promising application of IoT technology, but also these devices and systems have the potential to enhance the quality of patients’ monitoring.

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1 Introduction

1.1 Project Overview

The Internet of Things (IoT) has made a great evolution over the years [1]. It is a system of devices, some with built-in sensors, connected through the internet that collects data and apply analytics to extract valuable information. This information can be used to detect patterns, provide recommendations, and suggest future actions, etc. Today, applications of IoT systems can be observed in every domain especially in healthcare for remote monitoring of patients, even in real-time. The focus is not only to monitor vital signs and electrocardiogram (ECG) but the healthcare industry is working on telehealth, smart hospitals, wearables, etc. Most IoT systems are based on cloud-computing technology because it provides data storage, privacy, easily manageable data and unified access. Furthermore, because of IoT contributions in healthcare, the Internet of Medical Things (IoMT) has become a branch of IoT because of IoT contributions in healthcare [2].

The Internet of Things is bringing the healthcare industry a new life. One of the best ways is where the doctors can use the appropriate patient's digital information to take suitable decisions. It increases the quality of patient information in the medical field. mVitals will utilize edge computing in combination with intelligent IoT devices. This will allow the system to collect patient data, send it to edge server for noise reduction and provide real-time information. This system will use different sensors like ECG, heart rate, body temperature, blood pressure and breathing rate sensor to monitor patient's health. These sensors will be attached to a microcontroller like Arduino. To monitor a patient's health, the caretaker will use an end user device to screen the vitals, which would be connected to an edge server wirelessly.

1.2 Cloud Computing Based IoT Devices

IoT systems use several architectural approaches. Most IoT systems are based on cloud-computing technology, which provides data storage, privacy, easily manageable data and unified access. The Cloud computing method is dependent on the Internet that allows computers and other equipment to share software and hardware information[3].

1.3 Edge Computing Based IoT Devices

IoT devices are adapting edge computing because of the high costs and complexity in centralized systems. IoMT is adapting edge computing [4] over current centralized cloud infrastructure, because of increased demand of data driven care in the health industry. Edge computing is a decentralized architecture deployed in the proximity of the user to reduce latency and bandwidth utilization. It is more secure, efficient, inexpensive, and scalable; it also provides local manipulation of data [5]. Furthermore, in the healthcare monitoring system, the functionality can be very crucial for the patient in case of a low bandwidth rate. Edge computing solves this problem and is beneficial for applications that require intensive computations and low latency. Besides low latency, edge computing is preferred over cloud in remote locations as well, where there is limited or no connection to a central server location.

1.4 Objectives

- Design and implement an intelligent portable system for real-time healthcare monitoring.
- Develop a smart medical monitoring system that will utilize in hospitals, ambulances, etc. and collaborate with the smart home idea to make it part of daily life activities.
- Deploy deep learning techniques for training and testing of models, to provide reliable disease diagnosis.
- Design a system incorporating a Clinical Decision Support System (CDSS), which will enhance the patient's diagnosis with better analytics.
- Assist the doctors/caretakers to monitor the patient and provide a reliable notification mechanism in case of any critically.
- Make use of wireless technology, to get rid of jumbled up wired hardware systems and allowing patients to roam freely.
- Develop an edge computing based system backed up with the cloud services, to provide storage and analysis of data in real time.
- Store and manage the health record of the patients for different purposes.
- Provide an adequate visual representation of the patient's vital signs and ECG, so even a non-medical person can monitor the patient.
- Reduce the costs associated with employing expensive monitoring equipment.

1.5 Problem Statement

WHO (World Health Organization) country profile shows that in Pakistan 25.3% of individuals had high BP, 19% had CVD (Cardiovascular disease) diseases, 6% had chronic respiratory diseases [6]. Pakistan being a developing country does not possess the resources for medical treatment with the high population growth. A survey was conducted in 2017-2018 that showed there is only one bed for 1580 patients [7]. Doctors can't treat most of the patients with limited resources. A remote healthcare system is needed which may free up more beds in hospitals that can benefit patients who need urgent help. The recent pandemic situation has limited people only to their homes. This situation called for a remote healthcare system that could maintain safety between doctor and patient.

1.6 Assumptions and Constraints

1.6.1 Assumptions

- The system will develop for the real-time vital signs' monitoring of patients.
- The system will assist doctors towards reliable disease diagnosis using edge computing technology.
- A platform for doctors to examine the detailed continuous data of a patient`s vital signs with accuracy and visual representation.
- An online database-oriented system will keep the detailed data of each patient organized.

- An artificially intelligent system that will identify the disease and learn from the data acquired each time a patient uses the system and give useful suggestion towards the best treatment plans.

1.6.2 Constraints

- To use this system, the user must have mVitals device.
- The project must be completed in the giving period.
- Most of part of data will be stored on a cloud database, not on local devices.
- The user using this system must have basic knowledge of information technology devices i.e. mobile phones.

1.7 Project Scope

- Most of the current healthcare monitoring systems have jumbled up hardware. To tackle this problem, most of the functionalities performed by our system use wireless technology, such as Bluetooth.
- According to [8], due to insufficient equipment in hospitals for emergency conditions, patients suffer, and lives are at stake. To overcome this problem, an intelligent healthcare monitoring system is introduced, which continuously monitors the vital signs and ECG of patients through wirelessly connected devices.
- Transfer delay of trauma patients to hospitals, leads to complications and suffering [9]. Even seconds can make a difference. This was the motivation to introduce such a system that even a non-medical person could use to monitor vital signs and alert hospitals on time in case of any criticality.
- As the Electronic Health Records (EHRs) [10] are replacing paper records, the proposed system will store the patients' data in an online-secured database. This allows the authorized personnel to access the records anytime and anywhere.
- This system monitors vital signs and ECG of the patient remotely. Hence, reducing the effort of doctors and patients.
- This smart medical monitoring and diagnostic system will not only be utilized in hospitals, ambulances, etc. but also collaborate with the smart home idea to make it part of daily life activities.
- The system will use deep learning algorithms, which learn from past data of patients. It provides predictions about the critical condition of patients.

2 Requirement Analysis

2.1 Existing Systems Study

As the health industry begins to incorporate IoT devices and systems, many wired or unwired gadgets and armbands are developed to monitor patients' health in real-time. However, they are

either not very versatile or efficient. A fitness tracking smartwatch is introduced in [11] that collects and displays users' heart rate, steps in a day and calories burnt. However, it has only limited sensors and does not monitor all the vital signs such as oxygen level and respiratory rate. Thus, the scope of its health care monitoring functionality is limited.

A pulse oximeter is developed in [12] to determine the arterial oxygen saturation in the blood of the user, and heart rate during sports at high altitudes, etc. However, it also serves a single function and is a delicate device.

An e-Health system was developed in [13] to measure blood pressure, heart rate, electrocardiogram (ECG) & temperature. Afterward, the information is forwarded to an android application for analysis. However, this system uses only Bluetooth for communication among connected devices, which is not a long-range medium and has low bandwidth.

An Australian team has developed a gadget that can monitor blood pressure continuously [14]. It does not require uncomfortable cuffs on the arms to function; rather it is very easy to use the device. However, its accuracy drops to 83% during exercise.

Sotera Wireless Inc. developed a small and portable multipurpose device called ViSi Mobile [15]. It is capable of monitoring patients' heart rate, blood pressure, pulse rate, respiration rate, skin temperature, etc. in Figure 1. The major drawbacks of this device are that it is very expensive and usually works on cellular networks, which can be unavailable in some regions. However, some of the newer and expensive versions can also be connected via Wi-Fi. Figure 1 shows the hardware connectivity of ViSi Mobile with a human body, which has plenty of wires that could be irritating for the patient.

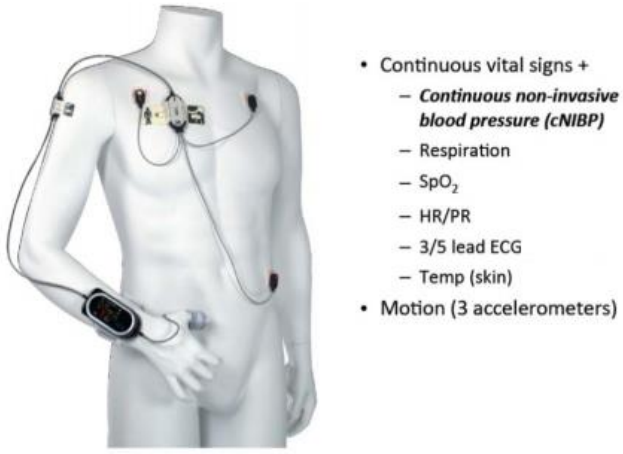

Figure 1- ViSi Mobile's Hardware [16]

2.2 Stakeholders List

- Doctor
- Paramedical Staff

- Healthcare Facilities
- Patient
- Caregiver
- AI Server

2.3 Requirements Elicitation

2.3.1 Functional Requirements

FR01: Signup

Req. No.	Functional Requirements
FR01-01	A doctor will be able to create an account and provide his/her information such as name, specialization, contact number, email, and hospital/clinic name. This record will be automatically stored in the database.
FR01-02	A patient will be able to create an account and provide his/her information such as name, age, contact name and email. This record will be automatically stored in the database.
FR01-03	The doctor as well the patient registered with that doctor will be able to access that particular doctor's profile after authorization.

FR02: Login

Req. No.	Functional Requirements
FR02-01	The patient and doctor will be able to log into the system and avail the features provided by the system.
FR02-02	The system shall allow the user to recover their forgotten password by recovery methods.

FR03: Edit Doctor's Profile

Req. No.	Functional Requirements

FR03-01	The system shall provide an interface to the doctor to edit his/her profile from the database.

FR04: Register New Patient

Req. No.	Functional Requirements
FR04-01	The doctor/caretaker will be able to register a patient and provide the patient's information such as name, gender, age, contact number, email, and date of birth, address and medical history.
FR04-02	Patient's information shall be automatically stored in the database and accessible by the doctor as well as the patient.

FR05: Edit Patient`s Profile

Req. No.	Functional Requirements
FR05-01	The system shall allow the patient to edit the profile from the system database.

FR06: Remove Patient

Req. No.	Functional Requirements
FR06-01	A patient will be able to remove his/her profile from the doctor's profile by the doctor, with whom he is registered, as well as by the patient himself.

FR07: View Vital Signs

Req. No.	Functional Requirements
FR07-01	The system shall allow the user to view an interface with all the vital sign information of the patient.

FR08: Search and access to Patient

Req. No.	Functional Requirements
FR08-01	The doctor will be able to view the list of all his/her registered patients.

FR08-02	The doctor will be able to view complete details of all his/her registered patients.
FR08-03	The doctor will be able to Search his/her registered patients.

FR09: Diagnosis and Treatment Plan

Req. No.	**Functional Requirements**
FR09-01	The system will provide automatic diagnosis and suggestions for treatment plans to the user. It will store meaningful data of the patients into the database and applies machine learning models to it for the system to learn and aid user.
FR09-02	The system will allow the doctor to edit the generated treatment plan of specific patient according to requirement.

FR10: Run Patient Diagnosis

Req. No.	**Functional Requirements**
FR10-01	The doctor will be able to manually run diagnosis, along with automatic diagnosis, on his/ her patients and view the results.

FR11: Set Appointment for Patient

Req. No.	**Functional Requirements**
FR11-01	The doctor will be able to set up an appointment for the patient in his/her treatment plan, provided by the system.
FR11-02	The doctor will be able to provide appointment details such as location, date, time, doctor's name, etc.

FR12: Alert Generation

Req. No.	**Functional Requirements**
FR12-01	In the case of criticality in the patient's condition, the system will send an alert to the patient's doctor, nearby hospital based on GPS or an ambulance.

FR013: View History

Req. No.	Functional Requirements
FR013-01	The doctor and patient will be able to view the historical data of the particular patient, which will be already stored in the system's database. They will allow us to click on a vital sign and a screen will display a history of that particular vital sign information for each hour, day or month.

FR014: View Report

Req. No.	Functional Requirements
FR014-01	The doctor and patient will allow us to view historical data of the particular patient, which will be already stored in the system's database.
FR014-02	Patients' real time as well as historic reports will be generated and viewed by doctors, patients and administrators.

FR015: Delete Account

Req. No.	Functional Requirements
FR015-01	The system will allow the doctor to permanently delete his/her account.
FR015-02	The system will allow the patient to permanently delete his/her account.

2.3.2 Non-Functional Requirements

NFR01: Performance and Scalability

NFR01-01	The starting page's average load time should not be more than 5 seconds.
NFR01-02	The average processing time taken by the system to complete the authentication process should not be greater than 5 seconds.
NFR01-03	System Mean Time to Failure (MTTF) should not be more than 1 minute.
NFR01-04	The average system response time should not be greater than 10 seconds.
NFR01-05	The system must successfully and effectively run on a client device with 2 GB RAM or above, 10 GB storage and a good internet connection.

NFR02: Security

NFR02-01	Only authorized users should be able to access the system.
NFR02-02	Any unauthorized users should not have any access control for the database.
NFR02-03	Any user should not be allowed to view history, report, diagnosis or treatment plans of other users.
NFR02-04	All acquired data from the sensors are directly saved to the cloud database.

NFR03: Defects-Maintainability

NFR03-01	The average defect escaped ratio of the system should not be more than 5% per month.
NFR03-02	Post Release defects fixing should not take more than 8 hours.
NFR03-02	Escaped defects should be fixed on system updates.

NFR04: User Documentation

NFR04-01	Complete documentation of the system should be provided to the user.
NFR04-02	To avoid any inconvenience, help options must be provided throughout the system.
NFR04-03	Help must easily accessible using tooltips and graphical representation.

NFR05: Data Recovery

NFR05-01	In case of system /server crashes all data should be recoverable within 30 minutes.

NFR06: Usability

NFR06-01	The system will be clear and responsive on each element.
NFR06-02	Each element should be represented with the help of an icon in the system.
NFR06-03	Sliders, tooltips and icons shall be used in the system.

NFR07: Data Integrity

NFR07-01	Acquired data must be filtered before saving in cloud database.
NFR07-02	Each user's data shall be stored separately.

2.4 Use Case Description

2.4.1 UC01: Sign Up

Use Case Name	Signup
Abstract	No
Purpose	To register new users to use/access system.
Actors	Doctor, Patient
Importance	Primary
Overview	This use case register new users and authorizes them to use system features according to user type.
Requirements	
Status	Essential
Uses	
Pre-conditions	None
Post-conditions	If registration is successful, the user will be logged into the system.

	Actor Actions	**System response**
	Typical Course of Actions	
	1. User starts the system.	
		1a. System requests to select user type.
	2. User selects user type and click on the text filled which are to be filled.	
	3. User clicks on ‘Sign Up’ button.	
		3a. System validates the user input, registers and logs user into the system.
	Alternative Course	
	1. User entered invalid text fields.	
		1a. System validates the user input and displays error message
	Exceptional Course	
		1a. Database connection error occurs.

2.4.2 UC02: Login

Use Case Name	Login
Abstract	No

Purpose	To authenticate users to use/access system.
Actors	Doctor, Patient
Importance	Primary
Overview	This use case authenticates users and authorizes them to use system features according to user type.
Requirements	
Status	Essential
Uses	Reset Password
Pre-conditions	Account should be created.
Post-conditions	If authentication is successful, the user will be logged into the system.

	Actor Actions	**System response**
	Typical Course of Actions	
	1. User starts the system.	
		1a. System requests to select user type and enter username and password.
	2. User selects user type and enters username and password.	
	3. User clicks on ‘Log In’ button.	
		3a. System validates the user input and logs user into the system.

	Alternative Course	
	4. User entered invalid username and/or password.	
		1a. System validates the user input and displays error message
	Exceptional Course	
		1a. Database connection error occurs.

2.4.3 UC03: Forget Password

Use Case Name	Forget Password
Abstract	No
Purpose	To authenticate users to recover their login password.
Actors	Doctor, Patient
Importance	Primary
Overview	This use case enables users to recover the forgotten password to their accounts.
Requirements	
Status	Essential
Uses	n/a
Pre-conditions	

Post-conditions	Password is set/changed.	
	Actor Actions	**System response**
	Typical Course of Actions	
	1. User clicks on "Forget Password" button.	
		1a. System displays a form with fields; email, new password, confirm new password,
	2. User enters email, new password, confirm new password,	
	3. User clicks on "Reset" button.	
		3a. System validates the user input and updates the current user password.
	Alternative Course	
	1. User entered invalid password format.	
		1a. System validates the user input and displays error message.
	Exceptional Course	
		1a. Database connection error occurs.

2.4.4 UC04: Reset Password

Use Case Name	Reset Password
Abstract	No
Purpose	To authenticate users to reset login password.
Actors	Doctor, Patient
Importance	Primary
Overview	This use case enables users to reset the passwords to their accounts.
Requirements	
Status	Essential
Uses	
Pre-conditions	User is logged in using old password.
Post-conditions	Password is set/changed.

	Actor Actions	**System response**
	Typical Course of Actions	
	4. User clicks on "Change Password" button.	
		1a. System displays a form with fields; current password, new password, confirm new password,

	5. User enters current password, new password, confirm new password,	
	6. User clicks on "Reset" button.	
		3a. System validates the user input and updates the current user password.
	Alternative Course	
	2. User entered invalid password format.	
		1a. System validates the user input and displays error message.
	Exceptional Course	
		1a. Database connection error occurs.

2.4.5 UC05: Edit Profile

Use Case Name	Edit Profile
Abstract	No
Purpose	To enable patients and doctors to edit profile information.
Actors	Patient, doctor
Importance	Primary
Overview	This use case will enable patients and doctors to edit their profile information like contact number, address, email address.

Requirements		
Status	Essential	
Uses	Authentication	
Pre-conditions	Patient/doctor is logged in and authorized.	
Post-conditions	Patient/doctor has made changes in profile information.	
	Actor Actions	**System response**
	Typical Course of Actions	
	3. Patient/doctor enters 'Edit Profile' section.	
	4. Patient/doctor clicks on the text field that is to be edited.	
	5. Patient/doctor inputs new details and click on 'Update Info' button.	
		5.a. System validates the input data from Patient/doctor.
		5.b. System updates the new profile details in database and displays success message.
	Alternative Course	
		Data input format not correct – System displays error message.

	Exceptional Course	
		1a. Database connection error occurs.

2.4.6 UC6: Delete Account

Use Case Name	Delete Account	
Abstract		
Purpose	To enable doctor and patient to permanently delete account.	
Actors	Doctor, Patient	
Importance	Primary	
Overview	This use case will enable the doctor and patient to permanently delete account.	
Requirements		
Status	Essential	
Uses		
Pre-conditions		
Post-conditions	Account deleted.	
	Actor Actions	**System response**
	Typical Course of Actions	
	1. Doctor/Patient clicks on the “Profile” button.	

		1a. System will display profile of doctor/patient.
	2. Doctor/Patient clicks the "Edit Profile" button.	
		1a. System allows the doctor/ patient to edit the profile.
	3. Doctor/Patient clicks the "Delete Account Permanently" button.	
		1a. System will delete the account permanently.
	Alternative Course	
		Error while deleting the account – System displays error message.
	Exceptional Course	
		1a. System error occurs.

2.4.7 UC7: Patient Registration

Use Case Name	Patient Registration
Abstract	
Purpose	To enable doctor to register a new authorized patient.
Actors	Doctor
Importance	Primary

Overview	This use case will enable the doctor to register a new authorized patient in his/her profile.
Requirements	Patient's account should be made.
Status	Essential
Uses	
Pre-conditions	Doctor must be logged in the system. Patient is present in the database
Post-conditions	New patient will register in doctor's profile.

	Actor Actions	**System response**
	Typical Course of Actions	
	4. Doctor clicks on the "Add New Patient" button.	
		1a. System will display the text fields for adding patient's information.
	5. Doctor fills the text fields for adding patient's information and clicks "Add" button.	
		1a. System will add the patient.
	Alternative Course	
		Error while adding patient – System displays error message.

	Exceptional Course	
		1a. System error occurs.

2.4.8 UC8: View History

Use Case Name	View History	
Abstract		
Purpose	To enable patient and doctor whom that particular patient is registered, to view history.	
Actors	Patient, Doctor	
Importance	Primary	
Overview	This use case will enable the patient and their doctor to view the history.	
Requirements		
Status	Essential	
Uses		
Pre-conditions	The patient's vital sign data should be present in system database. Patient/Doctor is logged in and authorized.	
Post-conditions	History of patient has shown.	
	Actor Actions	**System response**
	Typical Course of Actions	

	Patient or doctor clicks on the "View History" button.	
		System will display the history records of patient.
	Alternative Course	
		Error while opening history – System displays error message.
	Exceptional Course	
		1a. mVitals device connection/configuration error occurs.
		2a. System error occurs.

2.4.9 UC9: View Report

Use Case Name	View Report
Abstract	
Purpose	To enable patient and doctor whom that particular patient is registered, to view report of patient's vital signs.
Actors	Patient, Doctor
Importance	Primary
Overview	This use case will enable the patient and their doctor to view the report of the patient's vital signs.
Requirements	Continuous real-time data gathering and storing.
Status	Essential

Uses		
Pre-conditions	Patient/Doctor is logged in and authorized.	
Post-conditions	Report of patient has shown.	
	Actor Actions	**System response**
	Typical Course of Actions	
	Patient or doctor clicks on the "Generate Report" button.	
		System will display the generated report recorded vital signs of patient.
	Alternative Course	
		Error while generating report – System displays error message.
	Exceptional Course	
		1a. mVitals device connection/configuration error occurs.
		2a. System error occurs.

2.4.10 UC10: View Diagnosis

Use Case Name	View Diagnosis
Abstract	
Purpose	The doctor will be provided a set of diagnosis by the system from the acquired data of the registered patient.

Actors	Doctor
Importance	Primary
Overview	This use case will enable the doctor to view the diagnosis from the acquired data of the registered patient.
Requirements	The patient should be registered by the doctor.
Status	Essential
Uses	
Pre-conditions	Doctor is logged in and authorized. Patient is added and present in the database.
Post-conditions	A list of diagnosis will display.

	Actor Actions	**System response**
	Typical Course of Actions	
	Doctor clicks on the “Diagnosis” button.	
		System will display the list of diagnosis from the patient’s data.
	Alternative Course	
		Error while diagnosis process – System displays error message.
	Exceptional Course	

		1a. System error occurs.

2.4.11 UC11: View Treatment Plan

Use Case Name	View Treatment Plan	
Abstract		
Purpose	To enable doctor to generate treatment plan suitable for patient.	
Actors	Doctor	
Importance	Primary	
Overview	This use case will enable the doctor to generate a treatment plan for the patient.	
Requirements	Patient registering by the doctor.	
Status	Essential	
Uses		
Pre-conditions	The data history of patient's vital signs should be present in system.	
Post-conditions	Treatment plan generated by the system displays.	
	Actor Actions	**System response**
	Typical Course of Actions	
	Doctor clicks on the "Treatment Plan" button.	

		1a. System will display the treatment plan suitable for the patient.
	Alternative Course	
		Error while generating treatment plan – System displays error message.
	Exceptional Course	
		1a. System error occurs.

2.4.12 UC12: Edit Patient's Treatment Plan

Use Case Name	Edit Patient's Treatment Plan
Abstract	
Purpose	To enable doctor to edit the generated treatment plan for patient.
Actors	Doctor
Importance	Primary
Overview	This use case will enable the doctor to edit the already generated treatment plan of the patient according to requirements.
Requirements	Patient registering by the doctor.
Status	Essential
Uses	
Pre-conditions	

Post-conditions	Edited treatment plan displays.	
	Actor Actions	**System response**
	Typical Course of Actions	
	1. Doctor clicks on the "Treatment Plan" button.	
		1a. System will display the treatment plan suitable for the patient.
	2. Doctor clicks on the "Edit" button.	
		1a. System allows the doctor to edit the generated treatment plan of patient.
	Alternative Course	
		Error while editing the treatment plan – System displays error message.
	Exceptional Course	
		1a. System error occurs.

2.4.13 UC13: Remove Patient

Use Case Name	Remove Patient
Abstract	
Purpose	To enable doctor to remove patient from his/her profile.

Actors	Doctor
Importance	Primary
Overview	This use case will enable the doctor to remove a patient from his/her profile.
Requirements	Patient registering by the doctor.
Status	Essential
Uses	
Pre-conditions	
Post-conditions	Patient removed.

	Actor Actions	**System response**
	Typical Course of Actions	
	6. Doctor clicks on the "Registered Patients" button.	
		1a. System will display all the patients registered by doctor.
	7. Doctor select the patient to be deleted and clicks "Delete" button.	
		1a. System allows the doctor to delete the patient.
	Alternative Course	

		Error while deleting the patient – System displays error message.
	Exceptional Course	
		1a. System error occurs.

2.4.14 UC14: View Vital Signs

Use Case Name	View Vital Signs	
Abstract		
Purpose	To enable patient to view his/her vital signs.	
Actors	Patient	
Importance	Primary	
Overview	This use case will enable the patient to view his/her vital signs.	
Requirements	mVitals device should be connected/configured properly.	
Status	Essential	
Uses		
Pre-conditions	Patient is logged in and authorized.	
Post-conditions	Vital signs shows.	
	Actor Actions	**System response**
	Typical Course of Actions	

	1. Patient logged in and connect device.	
		1a. System will display all vital signs of patient.
	Alternative Course	
		Error while displaying vital signs of the patient – System displays error message.
	Exceptional Course	
		1a. System error occurs. 2a. mVitals device connection/configuration error.

2.4.15 UC15: Search Patient

Use Case Name	Search Patient
Abstract	No
Purpose	To enable doctor to search patient from the database and view his profile.
Actors	Doctor
Importance	Primary
Overview	This use case will enable doctors to search patients from the database and view his profile information and perform any other action he is allowed to perform.
Requirements	
Status	Essential

Uses		
Pre-conditions	Doctor is logged in and authorized. Patient is added and present in the database	
Post-conditions	Patient is displayed.	
	Actor Actions	**System response**
	Typical Course of Actions	
	Patient enters ‘Search Patients’ section.	
		System displays list of all the Patients in database.
	Alternative Course	
		No Patient is found– System displays error message.
	Exceptional Course	
		Database connection error occurs.

2.4.16 UC16: Alert Messages

Use Case Name	Alert Messages
Abstract	No
Purpose	To send alert messages to doctor in case of emergency.
Actors	Doctor

Importance	Primary
Overview	This use case will enable alert generation and send it to the patient's doctor.
Requirements	
Status	Essential
Uses	
Pre-conditions	Doctor is logged in and authorized. Patient is logged in and authorized.
Post-conditions	Alert messages send.

	Actor Actions	**System response**
	Typical Course of Actions	
	Abnormal readings coming from the mVitals device.	
		System sends alert notifications to the patient's doctor/nearby hospital.
	Alternative Course	
		No Doctor is found– System displays error message.
	Exceptional Course	
		Database connection error occurs.

2.4.17 UC17: Set Appointment

Use Case Name	Set Appointment
Abstract	No
Purpose	To enable doctor to set an appointment for the patient.
Actors	Doctor
Importance	Primary
Overview	This use case will enable doctors to set an appointment for the patient.
Requirements	
Status	Essential
Uses	
Pre-conditions	Doctor is logged in and authorized. Patient is added and present in the database
Post-conditions	Patient is displayed.

	Actor Actions	**System response**
	Typical Course of Actions	
	1. Doctors clicks "Set Appointment" button.	
		1a. System will display a form of text fields i.e. select patient, time and date.

	2. Doctor fills the text fields i.e. select patient, time and date and clicks "Set" button.	
		1a. System will set an appointment for the patient.
	Alternative Course	
		No Patient is found– System displays error message.
	Exceptional Course	
		Database connection error occurs.

2.4.18 UC18: Data Acquisition

Use Case Name	Data Acquisition
Abstract	
Purpose	To enable system to acquire data from the mVitals device for the vital signs monitoring.
Actors	AI Server
Importance	Primary
Overview	This use case will enable AI server to get data from the bodysuit, process it, extract required features from it and identify disease or whether the person has disease or not.
Requirements	
Status	Essential

Uses		
Pre-conditions	mVitals device is connected and configured properly.	
Post-conditions	Data is acquired from the mVitals device.	
	Actor Actions	**System response**
	Typical Course of Actions	
	mVitals device is configured and patient wears it.	
		AI server gets all the data coming from the sensors of mVitals device.
	Alternative Course	
		Device not connected or configured properly– System displays error message.
	Exceptional Course	
		Connection error occurs. Configuration error occurs.

2.4.19 UC19: Data Processing

Use Case Name	Data Processing
Abstract	
Purpose	To enable the system to process the acquired data.
Actors	AI Server

Importance	Primary
Overview	This use case will enable AI server to process the data acquired from the mVitals device. Processing includes noise removal from the data and data normalization to remove any unnecessary data.
Requirements	
Status	Essential
Uses	Data Acquisition
Pre-conditions	Data is acquired from the mVitals device.
Post-conditions	The data is processed properly and is ready for further use.

	Actor Actions	System response
	Typical Course of Actions	
	AI server gets the data from the mVitals device and applies some methods to process it.	
		Data is processed and ready for further use.
	Alternative Course	
		Data not found or unable to process data– System displays error message.
	Exceptional Course	
		Data acquisition error occurs. System error occurs.

2.4.20 UC20: Feature Extraction

Use Case Name	Feature Extraction	
Abstract		
Purpose	To enable AI server to extract required features from the processed data.	
Actors	AI server	
Importance	Primary	
Overview	This use case will enable AI server to extract required features from the processed data that will be further classified and on the basis of these features, diagnosis will be carried out.	
Requirements		
Status	Essential	
Uses		
Pre-conditions	Data is acquired and processed properly.	
Post-conditions	Required features from the data are extracted.	
	Actor Actions	System response
	Typical Course of Actions	
	AI server will extract required features for diagnosis purpose from the processed data.	
		Required features for diagnosis are extracted.

	Alternative Course	
		Unable to perform the required action– System displays error message.
	Exceptional Course	
		System error occurs.

2.4.21 UC21: Diagnosis

Use Case Name	Diagnosis
Abstract	
Purpose	To enable system to identify the fluctuation in vital signs and diagnosis diseases.
Actors	AI server
Importance	Primary
Overview	This use case will enable the system to diagnose the disease from the vital signs of patients and decide if the fluctuation of vital signs are at dangerous level.
Requirements	
Status	Essential
Uses	
Pre-conditions	mVitals device is connected/configured Properly
Post-conditions	Fluctuation in vital signs is identified and details are displayed to the doctor.

	Actor Actions	**System response**
	Typical Course of Actions	
	AI server identifies the fluctuation in vital signs using some machine learning algorithm.	
		Abnormal readings are identified and displayed to doctor.
	Alternative Course	
		System failed– System displays error message.
	Exceptional Course	
		System error occurs.

2.4.22 UC22: Treatment Plan

Use Case Name	Treatment Plan
Abstract	
Purpose	To enable system to prepare a treatment plan from acquired data.
Actors	AI server
Importance	Primary
Overview	This use case will enable the system to create a treatment plan from the acquired data and decides which treatment should be better for the patient according to patient's vital signs readings.

Requirements		
Status	Essential	
Uses		
Pre-conditions	mVitals device is connected/configured Properly	
Post-conditions	Treatment plan for the patient is created and displays to the doctor.	
	Actor Actions	**System response**
	Typical Course of Actions	
	AI server create treatment plan using some machine learning algorithm.	
		Treatment plan is created and displayed to doctor.
	Alternative Course	
		System failed– System displays error message.
	Exceptional Course	
		System error occurs.

2.5 Use Case Design

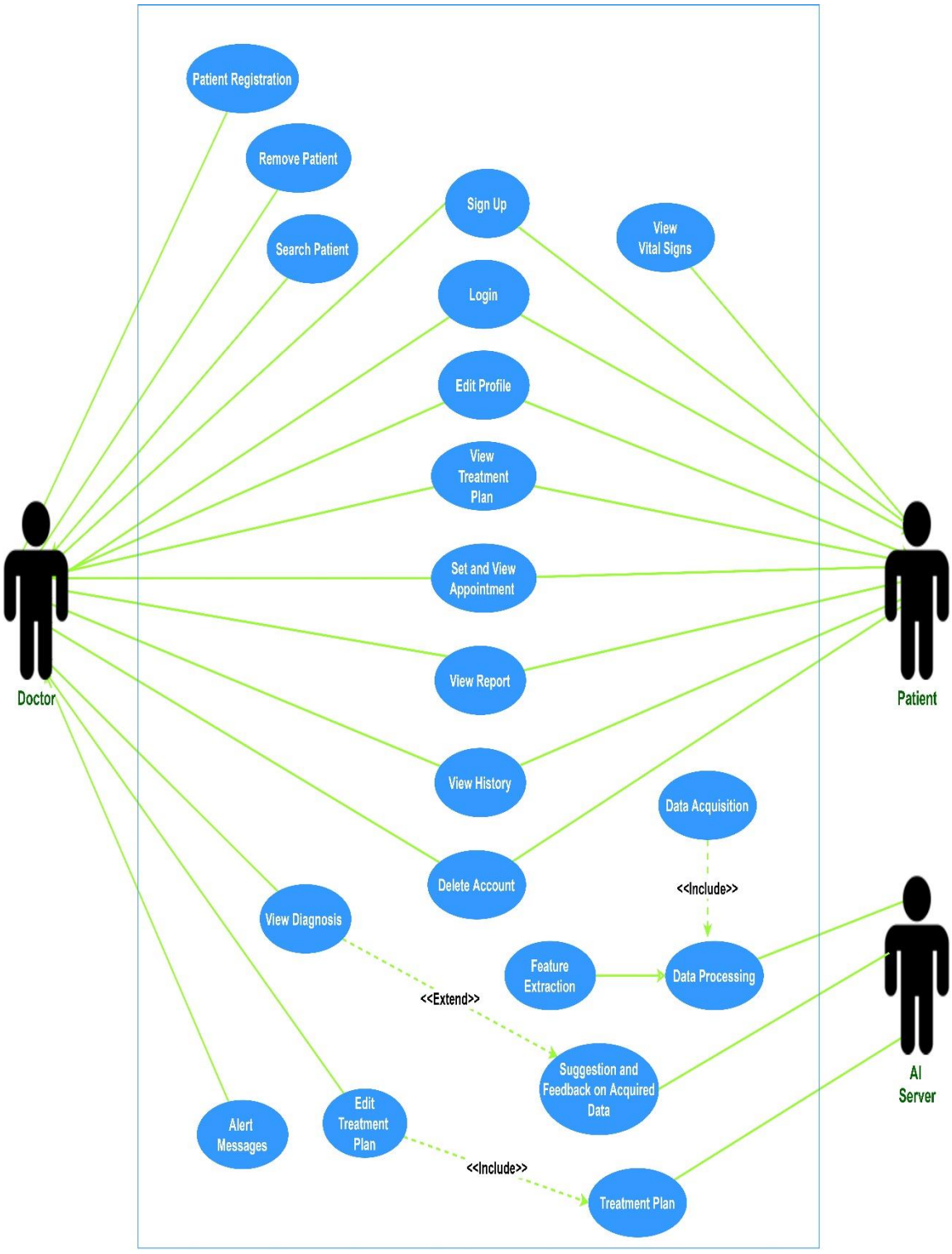

Figure 2- Use Case Diagram of System

2.6 Software Development Life Cycle Model

For the implementation of this project, Scrumban, an agile project development methodology that is hybrid of Scrum and Kanban, will be deployed.

2.6.1 Why Use Scrumban Model?

Scrumban is widely used in the development and maintenance of projects. We are adapting this methodology because it embraces the features of both Scrum and Kanban where the former is used as a way of working and the latter is used to view, understand and improve performance. It also uses key metrics to estimate the average time for completion of a specific task, a highly versatile approach for workflow management, reduces the impact of errors, increases productivity and waste minimization efficiency.

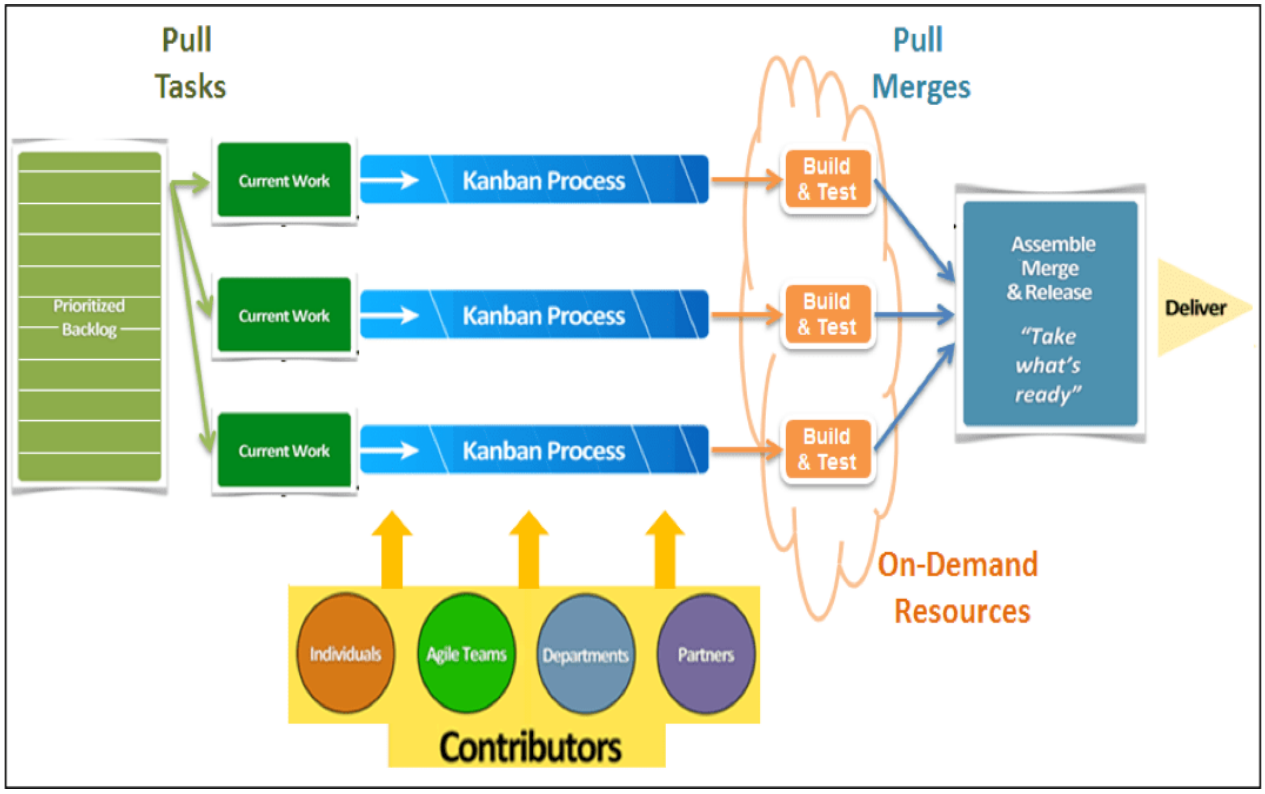

Figure 3- SDLC Model for the System [17]

3 System Design

3.1 Work Breakdown Structure (WBS)

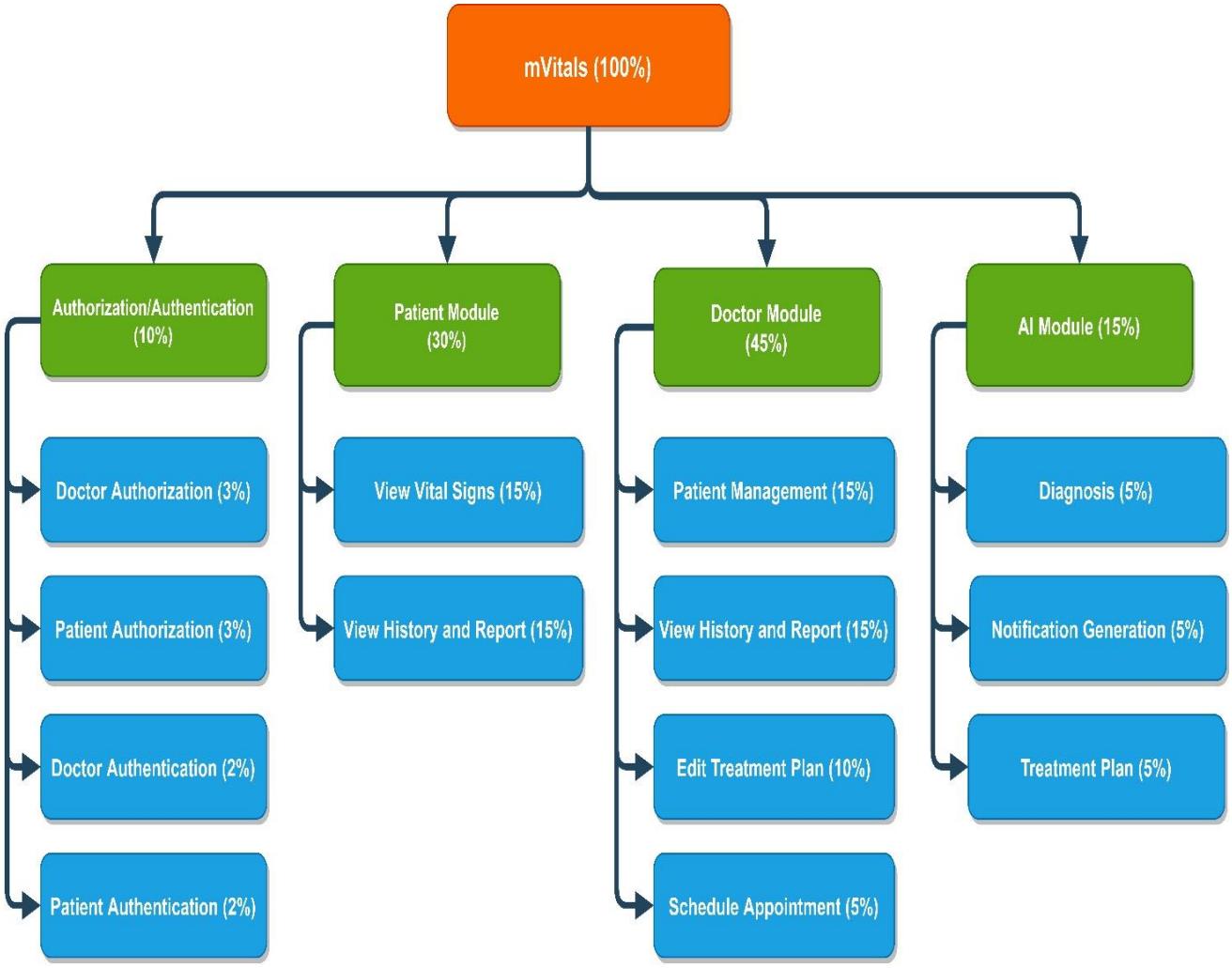

Figure 4- Work Breakdown Structure of System

3.2 Software Architecture

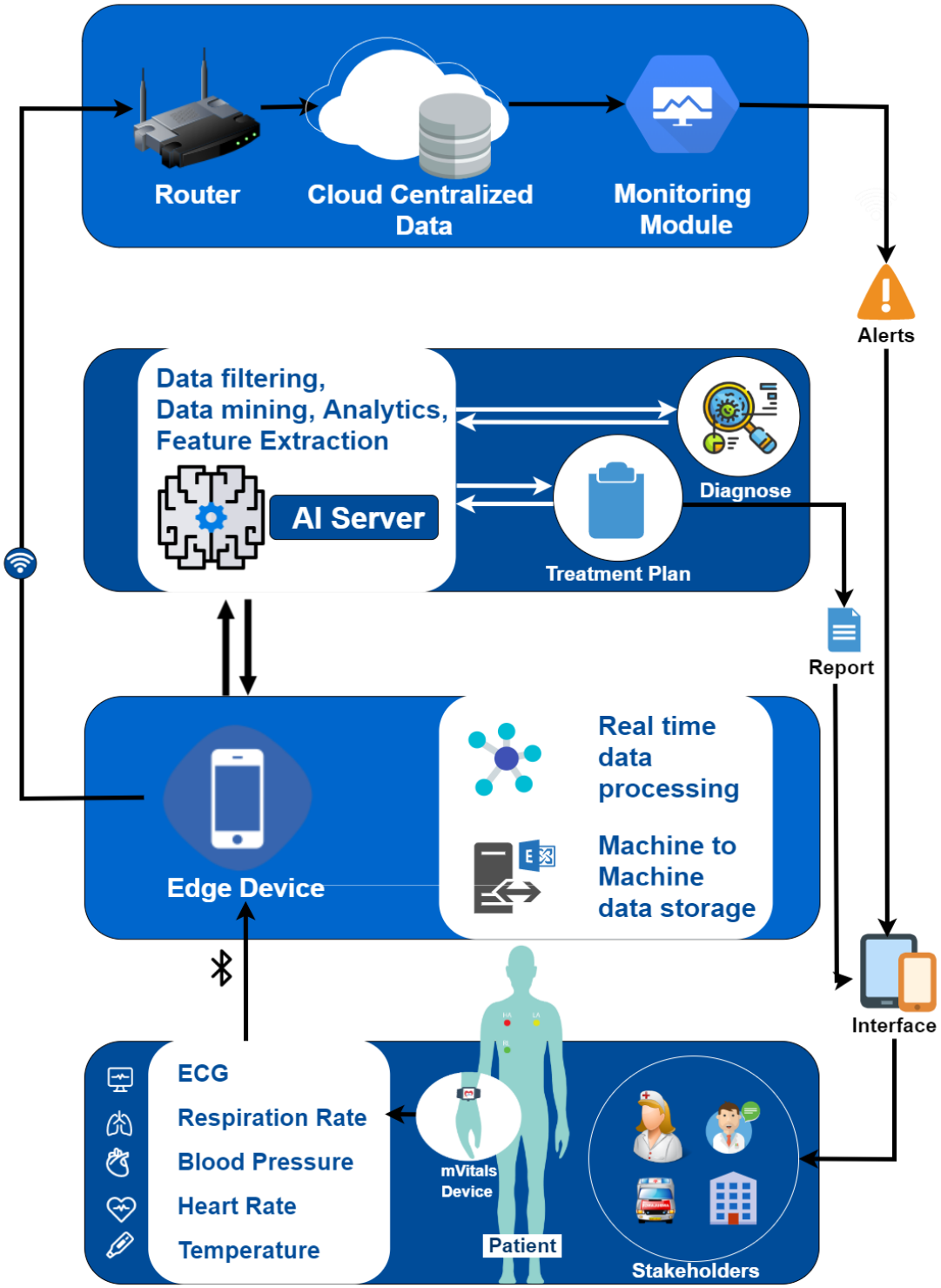

Figure 5- Architecture Diagram of mVitals System

Figure 5 shows an architecture of IoT based health monitoring system that has 4 layers moving from bottom to up. The first layer is a data accusation layer where sensory data of a patient is gathered using wearable sensors. The second layer is the networking layer, which is responsible for connecting an IoT wearable device through Bluetooth to an edge device. Data is stored temporarily in an edge device to reduce latency and bandwidth utilization. As we move up to the 3rd layer that is the processing layer, which is accountable for data filtering, data analysis and feature extraction for an AI module. In the AI module by using machine learning algorithms a diagnosis will be generated as well as a treatment plan. Diagnose and treatment plans will be accessible to both patients and doctors using an interface. Furthermore, it will aid in generating a report of patient's condition. The last layer is the application layer where an edge device is connected with cloud centralized storage via Wi-Fi through an internet router. The centralized data can be accessed through a monitoring module, where an app will be installed in patients' and doctors' phone or tablet. Through which both will be able to monitor the real-time physiologic parameters of a patient at the same time. In this layer, the system will be able to generate alerts if a patient's condition gets critical. The system will allow the doctors to manually add diagnoses and change the course of treatment if needed.

3.2.1 Wireless Sensor Environment

All the sensors will be encapsulated inside a wireless device and this device will wirelessly connect with the system via a microcontroller. The patient will only need to wear the device and the sensors will automatically start collecting the data. As the device will be portable, patients will allow to roam freely in the network.

3.2.2 Real-time sensor Data Acquisition:

The vital signs sensors will record the patient's physiologic parameters using ECG Module (AD8232), heart rate sensor XD-58C, body temperature sensor LM-35, blood pressure sensor CPS120 and breathing rate sensor ADS1292R on real-time with the help of microcontroller i.e. Arduino Nano. Filtration will be applied on this acquired data to remove noise and then transfer it to the cloud via edge server i.e. Raspberry Pi.

3.2.3 Authentication and Authorization Module

Patients or Doctors will be able to create their accounts and then login using the information they entered while creating their profile. Once logged in patients or doctors will be able to use services/features provided by the system.

3.2.4 Patient Module

In Patient module, patients will be able to view their history, real-time monitor their viral signs. Patients will also be able to view the report generated by the system based on task progress, medical analysis, and doctor feedback. Patients will also be able to look at the treatment planned by their doctors. Patient will get notified in a critical situation as well as their doctors.

3.2.5 Doctor Module

In Doctor module, the doctor register or delete a patient from their profile as well as system database. The doctor will be able to view the list of patients registered to him. Doctor will also be able to view the real-time data of each patient. Doctor can also write a treatment plan, delete the plan, and modify the plan for each patient according to their needs. Doctor will be notified if any

of the patient is in critical condition. Doctors will also be able to diagnose the patients and add their diagnostics report to the system. Doctors will also be able to view the report generated by the system based medical analysis.

3.2.6 AI Module

In the AI module, the AI agent will be able to acquire data from the wearable sensors, process the data and extract required features from it using machine learning algorithms. AI agents will then generate a diagnosis and tell whether our patient is in critical condition or not. The AI agent will use machine-learning algorithms to analyse past data, to improve healthcare by predictions and better analytics.

3.2.7 Cloud Storage:

Long-time data processing and storage will be performed with the help of cloud services. The acquired values of all individual parameters from the edge server will be saved on the cloud separately. The cloud data is secured so that only authorized users could access the patient's information. Unlike the traditional databases, this information will be accessed instantly anywhere with high processing power. Long-time data processing and storage.

3.2.8 Monitoring Module:

In the monitoring module, patients/doctors will be able to monitor the real time data received from wearable sensors through an interface.

3.3 Database Diagram

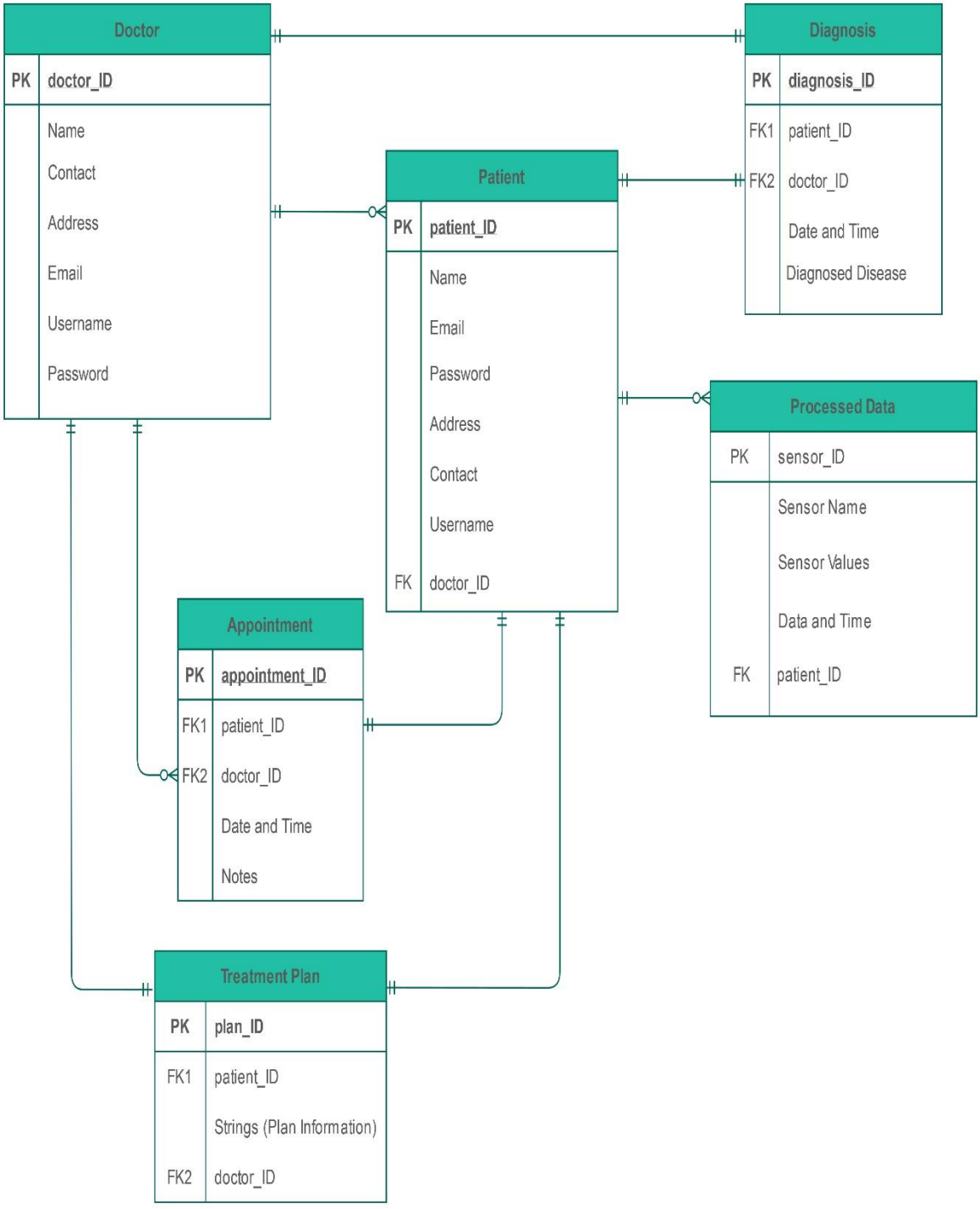

Figure 6- Database Diagram of mVitals

3.4 Network Diagram (Gantt chart)

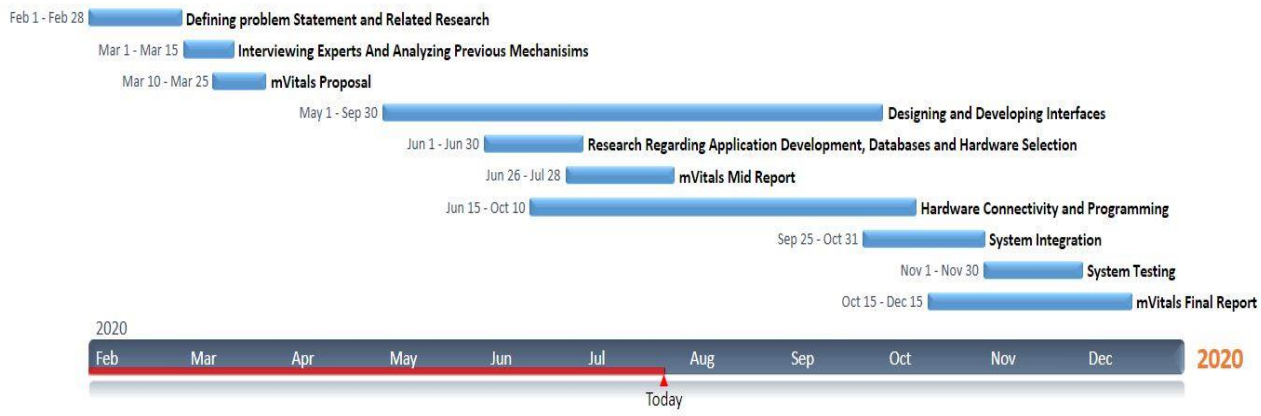

Figure 7-Gantt Chart of System

4 Conclusion

The proposed system will be mobile and wearable enabling wireless communication to continuously monitor vital signs and ECG of a patient. The system will utilize Bluetooth for communication between devices making it highly portable. Due to portability, the patient wearing wearable sensor-device will be able to move freely while the caretaker/doctor can view vital signs information from his mobile device without being physically present with the patient. The system will store records of patients' history as well as real-time monitoring data for future reference. The purpose was to present a design of a middleware platform to support better data acquisition operations in mobile health care monitoring environments. The data will be stored in a secure and efficient database system and only authorized people will have the remote accessibility of a patient's medical records, regardless of whereabouts with high processing speed. Incorporation of Clinical Decision Support System (CDSS) will enhance the patient's diagnosis and provide better analytics using deep learning techniques. The system will aid in devising treatment plans for patients based on deep learning and past data. This cost effective and efficient system will represent data in an easy to understand manner. Alerts and notifications will be sent to the concerned person in case of any critical change in the health parameters of patients so that the patient never stays unobserved. The aim is to improve the quality of life related to health care, with the help of continuous monitoring. The health caretakers can screen, analyse and diagnose their patients constantly. The proposed system uses machine-learning algorithms to analyse past data, to improve healthcare by predictions and better analytics. It will not only be available in the hospitals and ambulances but will also be integrated with the smart home systems.

4.1 Problems Faced and Lessons Learned

After the submission of the proposal, different problems related to the domain, tools and technologies for the system were faced. The first issue encountered was that whether we use

Arduino or Raspberry Pi. So, after consulting with our field related teacher we decided to use Arduino Nano as our microcontroller. Another issue encountered and that was of choosing appropriate sensors for vital signs. After detailed analysis, ECG Module (AD8232), heart rate sensor XD-58C, body temperature sensor LM-35, blood pressure sensor CPS120 and breathing rate sensor ADS1292R were selected. These problems helped us to learn about the system domain, required tools and in detail and depth.

4.2 Future Work

- More sensors such as diabetes sensor, Electrocardiography (ECG) with 12 leads (limb and precordium leads), etc. will be installed on the system for more accuracy and detailed monitoring.
- mVitals with implementation of VR technology and adaptation for Microsoft HoloLens.
- The system can be installed in the hospitals of the entire city, which will be connected to a centralized server for more experienced monitoring.
- In the future, the system can be incorporate with the smart medication system for the right dose.

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