A SMRT-RPMS-APP: A NOVEL REMOTE PATIENT MONITORING SYSTEM FEATURING VITAL SIGNS VIA SMART PHONES.

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Abstract*—The world's need for health professionals is in flux, medical staff face many difficulties while monitoring patients 24 hours continuously in case of I.C.U . Also there are limited available medical professionals especially for ECG/EEG activity; people find it quite difficult to access within their range. Smrt-rpms-app is a system that provides a helping hand in bridging a patient to such concerned Medical Professional. It is all about trending the Smart phones and the technology developers to facilitate medical field through hot Android based technology. The proposed Smrt-rpms-app is fully designed for the heart patients, that offers patients another way for treatment at their home regularly with special medical conditions. Smrt-rpms-app is able to tackle the monitoring issue by carry out remote monitoring vital signs parameters (the ECG, pulse-rate and body-temperature) data in patients, transmitted through App based WSN communication between a patient and medical personnel using a smart-phone. In project, we used Arduino, and smart, wireless sensors, and a Bluetooth module.*

Keywords - Smrt-rpms-app, ECG / EEG, WSN, RPMS, Arduino Bluetooth module.

I. INTRODUCTION

The number of deaths are approaching to millions caused by the growing population and the affordability of expenditures for health care. The demand of era is quality health-care systems from remote areas. The technological improvements in the field of medical and relevant fields have reduced the cost and expenses for health-care. This research introduces real-time heart monitoring system. This system takes the signals of ECG from the patient employing sensors, and then sends those to the smart phone device using Bluetooth module, then mobile device transmits those signals to web server through the Internet.

The WHO - World Health Organization has highlighted the disturbing worldwide deficiency of about 4.3 million nurses and doctors, who represents a deficit of 15% of the total number of nurses and doctors required worldwide. According to WHO, There is need of 12.9 million medical professionals worldwide by the year 2035. Today Pakistan is facing quite challenging situation in the perspective of increase in different diseases and it's quite challenging to fight out these diseases and such diseases are the reason of increased death rate.

Through the simple approach we can deal that 68% of smart phone users use Android Operating system.

As WHO Statistics 2012-13, obviously shows that almost 25% of people of more than 18 years are undergoing hypertension, 25% of people having age more than 40 years undergoing heart-disease and majorly 10% of adults suffers from diabetes. The above mentioned actions are adolescent of Vital signs since are measurements of the body's most essential functions to be monitored thus it demands great care and in accurate ways. As we started studying the problem we found numerous projects and different methodologies focusing to the similar problem" remote patient monitoring system" but all of these having different approaches and methodologies. Remote patient monitoring (RPM) systems are rapidly sprouting. The increased number of old age people and the patients undergoing diseases, it is necessary to provide competent transportable healthcare services by exploring the procedure of modern information and communication technologies. The incorporation of wireless communications and mobile devices with healthcare service deliverance allows for evolution of patients from inactive recipients to active participants in the process of decision-making and health management.

The total number of patients adopting remote monitoring devices is anticipated to boost radically in the future, with tendencies of RPMS becoming standard health-care service. Smart devices, particularly smart phones have been an important part of routine life, used not only for communication purposes, but in medical and health-care as well [1]. As the data relating health and applications are being transferred to the cloud computing systems by smart phones, it is firm that their role will become even morenoteworthy for investigation of biomedical signals and patient-related data. Mobile devices in remote monitoring were initially used only for the data transmission to the remote location and visualization, while server-side part was responsible for providing feedback to the patient and the storage purpose.

The speedy improvement of smart phones features brought in the opportunities for the smart phone-based local study that can be implemented in real-time. Therefore, it is desirable to present fast, rigorous solutions based on the smart phones to spawn immediate warnings in emergency cases. Though, smart phones are above all projected for the purpose of communication and their deployment in remote patient monitoring should be used for specific situations, such as lack of medical care, loss of cellular network signal etc.

The proposed project is fully designed for the heart patients and for normal people living in Pakistan with efficient and reliable services provided at their door step. The heart patients can't make regular and daily visits to the hospital that's why they need an easy to use easily available sensor based system. Sensors are widely used these days to tackle many problems in various fields. Therefore utilizing the Sensors efficiently in medical will be a productive work, since a lot of working has been done in medical field and more to be done. Due to much diversity in field of medical there are many projects running in different areas, some of

those are critical systems. Thinking in that perspective it's quite challenging work to find out the solution in medical field, but it is not impossible to develop such kind of systems that can be helpful. Though "Remote Patient Information Monitoring System" has been completely adapted in developed countries. Thus we can observe tremendous change in form of decrease in mortality rates patients' health. Hence, remote patient monitoring system with focused research on vital signs through sensors is feasible in Pakistan's remote areas.

The proposed project 'Remote Patient Monitoring system with focused researched on vital signs' will use the pulse sensor and temperature sensors connected with Arduino mega that makes it cost-effective as compared to above discussed/referenced projects. Instead of ZigBee we the project proposers will use the Bluetooth module that will be cost-effective and accurate. This project is feasible in the proposed scenario. The proposed project will also help out in future research on other vital signs like blood pressure, ECG and breathing rate.

II. PROBLEM FORMULATION

In this research work, we have examined the android smart phone for the acquirement and analysis of multiple bio-medical signals, including electro-cardiogram (ECG), pulse rate, body temperature signals. The system is implemented in three parts, In first part all the real time signal acquisition through the functional apparatus like sensors is done, secondly signal processing operations on smart phone, with constant transmission of the data from the sensor node. The different algorithms for the detection of important physiological parameters from biomedical signals, such as heart rate and pulse rate value, have been implemented. Third scenario assumes that wireless sensor nodes operate for different biomedical signals, and send only required parameters. In addition, obtained biomedical signals have been captured, integrated with smart phone app its selected data content are then transferred to the web server, from where acquired from information of patient's posture and possible abnormalities could be handled by the doctor. Our results shows that Smrt-rpms-app is one of the best possible applications achieved through the android smart phones apps development, that could provide user friendly and interactive environment even to those that don' know how to read. This paper offers a better understanding to the smart phone developers that they will focus and promote an option of RPMS system, which in some cases already present but of no major use. It is significant to define which process is suitable for smart phone application when designing efficient RPMS and how we constructively utilize web data servers for patient-doctor interaction through WSN.

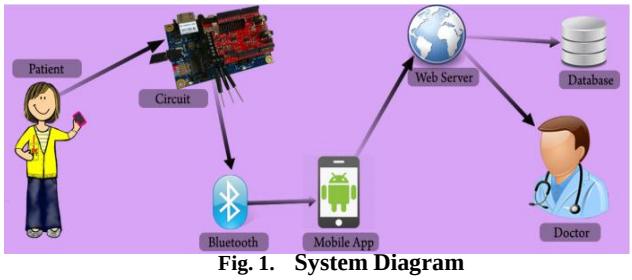

Fig. 1. System Diagram

III. LITERATURE REVIEW

There is done lot of work in the form of products and projects in remote monitoring of ECG by employing the latest technology like sensors. Earlier a monitoring system is proposed regarding health care[2]. The patients who need a constant monitoring and are in serious conditions to handle this author proposed a system with optimized protocol to balance the network load by employing the health care gateway and sensors[3]. In [3] the health care gateway is critical component that's why the Zigbee module is used to communicate the information among the sensor devices [4]. ECG vital sign monitoring devices have blood pressure, glucose, and body temperature parameters. The data is then transformed to a healthcare service information podium.

A ZigBee wireless sensor network based remote patient monitoring system and the IOT has been introduced in [5]. The system generates medical records saved in a database. The data is analyzed and the response is sent to remote location.

Two other ZigBee based systems were discussed using WPAN for remote patient monitoring in the general wards of a hospital [6]. A remote diagnosing system integrated with digital telemetry, used a remote patient unit that consists of two stations one is homecare station and other clinical station [7]. In [8] a wireless and wearable ECG sensor is introduced that pass on signals to an investigative station at the hospital. An ECG system has been discussed in [9] based on mobile platform which transmits jagged heartbeats recognized in a patient component. One more ECG analyzer system has been developed that captures the ECG signals, record the signals, and analyze the ECG signals on a personal digital assistant device carried by the patient [10]. A decision support system (DSS) model is discussed in [11] that is connected to hand-held device and it is provided to send an ECG signal to a hand-held device which will be able to provide remote cellular phone communication to speed up the analysis. In the electrical and computer engineering department of Cornell University, an ECG hardware design has been implemented to measure the electrical motion of the heart [12]. Another paper presented in which the design and implementation is done, and the results related to signals were store in the storage system of medical information linked to the ECG signal [13].

Table 1. Related patient monitoring systems

S.NO	SYSTEM	AUTHORS	ADVANTAGES	LIMITATIONS
1.	Telemedicine information monitoring system	Hsu Chih-Jen Center of Industrial Technology Research Institute, Hsinchu, Taiwan	The vital signs of patients will be transmitted via the Internet to hospitals or care centers, enabling the creation of an interactive relationship between medical staff and patients.	No app based interfacing. Separate controller and wireless module for transmission is used. No database record system.
2.	A Health Monitoring System Using Smart Phones and Wearable Sensors	Valerie GAY , Peter LEIJDEKKERS Faculty of IT, University of Technology Sydney,	research combines ubiquitous computing with mobile health technology and smart phones to monitor the wellbeing of high risk cardiac patients. The smart phone analyses real-time ECG data and determines whether the person needs external help.	The results of the sensors can be inaccurate due to noise and inaccurate readings. The monitoring system is only useful if we know the quality of the data we receive from the various sensors
3.	Personal Heart Monitoring and Rehabilitation System using Smart Phones	Peter Leijdekkers, Valerie Gay University of Technology Sydney	Prototype is capable of monitoring the health of cardiac patients. The smart phone app analyses in real-time sensors data and can automatically alert to the ambulance.	Monitoring is not ubiquitous in view of the privacy, mobility and flexibility issues concerning patients.

In this paper an adaptive real-time monitoring system is presented which currently facilitates cardiac patients but trending towards diabetic and EEG patients and follows up like a mini trained doctor.

So far this monitoring system provides updated online information about the patient's condition such as the patient's ECG, heart rate and history. Updates will be adjusted according to the doctor's needs.

IV. RESEARCH PROJECT OBJECTIVES

The purpose of this paper is to develop such a system through which doctor & Patients interact with each other remotely whenever they needed. We have proposed a web based sensor network system that would gather Pulse, Temperature, Blood Pressure & ECG readings from the patient & transmit it to the concerned Doctor.

The primary objectives of the project are:

- To develop an efficient remote patient monitoring system that can play important role in providing primary health-services in the field of medical science through technology.
- To provide a cost-effective and easily deployable Remote patient monitoring system using smart wearable.
- To implement the Sensors based system that will be easily accessible to the doctors located anywhere from remote areas.
- Smrt-rpms-app can get patients current & previous data of vital signs on the basis of which prescription be made by the doctor.
- To develop system that will improve the quality of health centers/government hospitals.
- To provide accessibility to Professional doctors who are available in limited numbers to rural/urban patients even who could not afford the consultancy.

Benefits:

- The greater part of Pakistan's population lives in rural areas with less equipped hospitals. Such hospitals can implement the proposed system to facilitate the people living in less developed areas.
- Medical field Industry will utilize this prototype project to make usable product for easy access of every one.
- Hospitals, health care centers and heart patient can take benefits of it.
- Govt. of Pakistan can use this technological based reliable and cost effective system in town hospitals which are far away from cities and the central data can be used for different research, surveys and analysis by using the data of patients (RPIMS) from different remote areas

V. IMPEMENTATION/ METHADOLOGY

The implementation methodology of this project is divided into two categories mainly; the hardware and software categories.

Hardware: we used the ECG Electrodes, pulse sensor, body temperature sensor, Arduino and Bluetooth module for Smart Phone.

*Software***:** we used the android application; web data server is specifically incorporated. Arduino 1.0.6 IDE to get data, App development through android studio, web page development & Patient display information using HTML, CSS, JavaScript and PHP language are used. The flow of working is shown below in flow chart.

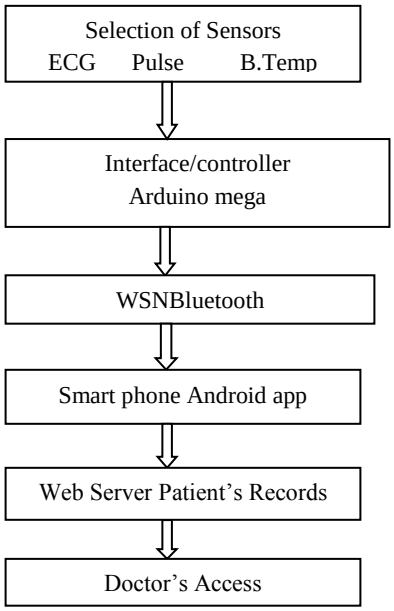

Fig. 2. Project working flow

Smrt-rpms-App has following sub-systems:

Patient sub-system: This comprises electrodes that sense the electrical activity of vital signs, signal acquisition. The sensor takes a reading whenever requested by the patient; the readings are wirelessly transmitted to the android phone app via Bluetooth then send it to the web server.

Android subsystem: Android based application that transmits the selected patient's vital sign details using smart phone.

Web-Server and Database sub-system: To display and store the patient's PR/ BT/ECG vital sign data and develop the outcomes that can be accessed by authorized group.

VI. HARDWARE SPECIFICATION

A. Hardware

In hardware of the system we have used the sensors and Arduino for getting the physiological data of patients. To do this we used Bluetooth module for sending data on mobile application.

B. Sensors

Sensors are the devices which measures or detect the physical data and responds in the form of electrical or optical signals [14]. The use of sensors in the computer science field is very trendy and useful. The use of sensors for the medical purpose is more realistic approach and for the vital signs is very important and complex. In this project Remote patient information monitoring through sensors is done, and two of the sensors are utilized for this purpose.

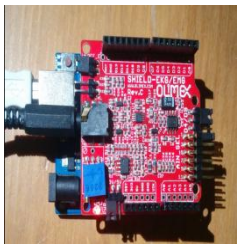

Fig. 3. ECG Sensor

C. ECG sensor:

ECG sensor is used to detect the electro-cardiogram signals of the patient. This sensor can determine the working status of heart in frequent intervals.

D. Pulse sensor

Pulse sensor is a plug and play sensor designed for the Arduino. It is used to integrate the live heart rate data into the projects; it is plugged into the Arduino through jumper cables. The pulse sensor is connected with finger or earlobe then it measures the data and sends to the Arduino for further processing. It is simple way of measuring the data and doctors prefer to take this data to analyze the stress, blood pressure etc.

Fig. 4. Pulse Sensor View

The pulse sensor connectivity with the Arduino is the key part for the transmission of signals or the pulse data of the patient. The basic diagram for the connectivity of both pulse sensor and Arduino is shown in following figure. In above diagram the pulse sensor is connected with the Arduino through cables and Arduino is given the power from external battery source.

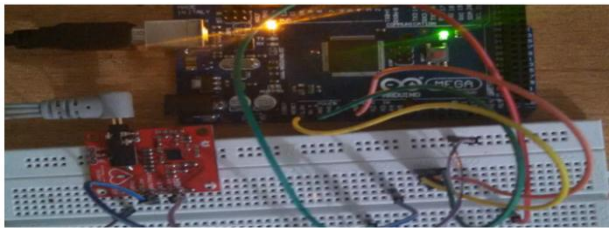

Fig. 5. Arduino-pulse sensor connectivity configuration

Arduino Pulse configuration

Sr	Arduino pins	Pulse sensor pins
1	GND	GND
2	3.3 v	3.3 v
3	A0	Output
4	Pin9	L0-
5	Pin8	L0+
6	-	SDN

The pulse sensor gives readings in the digital format. These readings are continuous; to use some specific readings there is some coding for it. The resultant output of the pulse sensor is shown in following figure:

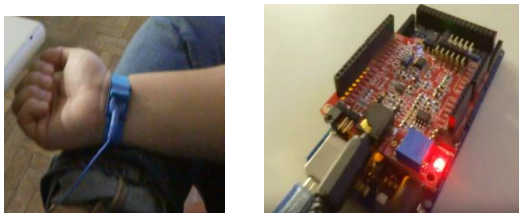

Fig. 6. Connectivity of arduino and ECG

VII. SIGNAL ACQUISITION & ANALYSIS & SOFTWARE IMPLEMENTATION

The wave form of the ECG, power spectral densities, and contoured plots are shown in fig.8 to see how the normal & anomalous electrical activity vector of the heart changes in fractions of a second. We have studied the entire ECG tracing of a normal cardiac cycle, which consists of a P wave, a QRS complex, and a T wave. Analysis of the QRS complex lets them see how the electrical activity vector is rotating while the heart beats. MATLAB code can be implemented to compute the heart rate, variations in R-R interval, P-R interval, and the S-T interval. These interval values have clinical significance.

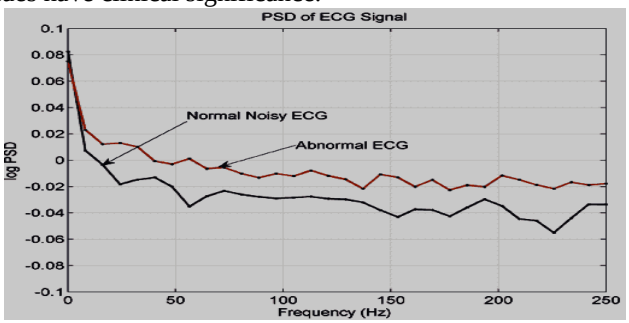

Fig. 7. Power spectral densities distributed over the frequency

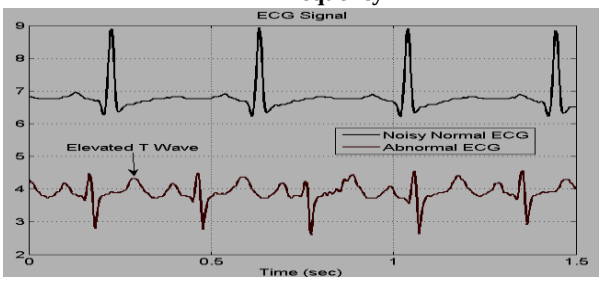

Fig. 8. A Normal Vs abnormal ECG

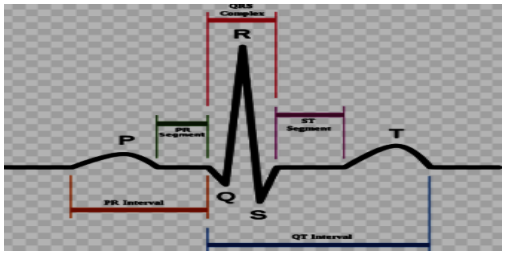

Fig. 9. PQRST Waves

ECG intervals

	Normal duration (sec)	
	Average	Range
PR interval	0.18	0.12-0.20
QRS duration	0.08	0.07-0.10
QT interval	0.40	0.33-0.43
ST interval (QT minus QRS)	0.32	

Fig. 10. ECG intervals

E. Body Temperature Sensor:

The body temperature is very important measure of the patient. The body temperature can be put into three major categories:

Table 2. Body Temperature categories

S. No:	Category	Range
1	Hypothermia	< 96.8°F
2	Normothermia	97.7°F to 99.5°F
3	Hyperthermia	>99.5°F

Hypothermia is most dangerous considered range of body temperature and it causes the coma or cardiac arrest to the patient. Mostly the thermometers are used for measuring the body temperature of patients. The difference of measuring the temperature between thermometer and the LM35 is briefly given as:

a) The thermometers which have thermistors can be proposed for the conductivity that is called intrinsic conduction the mathematical linear expression to show this is as in equation

$$\ln R_T = A + \frac{\beta}{T} \quad (1)$$

Where T = absolute temperature (Kelvin) and β (Beta) is assumed to be a material constant (Kelvin).

Now taking another equation which represents thermistor having resistance value as in equation (2) taken at time zero.

$$\ln R_{T_0} = A + \frac{\beta}{T_0} \quad (2)$$

And by solving the simultaneous equations (1) and (2), we obtain the following expressions:

$$\ln R_T - \ln R_{T_0} = \ln\left(\frac{R_T}{R_{T_0}}\right) = \beta\left(\frac{1}{T} - \frac{1}{T_0}\right) \quad (3)$$

We know natural logarithmic rule i.e.

$$\ln\left(\frac{A}{B}\right) = lnA - lnB$$

Thus:

$$\beta = \frac{\ln\left(\frac{R_T}{R_{T_0}}\right)}{\left(\frac{1}{T} - \frac{1}{T_0}\right)} \quad (4)$$

$$\left(\frac{1}{T} - \frac{1}{T_0}\right) = \left(\frac{1}{\beta}\right) ln\left(\frac{R_T}{R_{T_0}}\right)$$

Taking both sides logarithm

$$T = \beta\left(\frac{1}{\ln\left(\frac{R_T}{R_{T_0}}\right) + \left(\frac{\beta}{T_0}\right)}\right) \quad (5)$$

$$T = K = \beta\left(\frac{1}{\ln\left(\frac{R_T}{R_{T_0}}\right) + \left(\frac{\beta}{T_0}\right)}\right) \quad (6)$$

Therefore, if two points or a single point and the slope of the temperature are known, the equation can be solved for any unknown quantity for temperature [15] [16].

b) In the case of LM35, The accuracy specifications of the LM35 are given with respect to a simple linear transfer function:

$$V_{OUT} = 10 \text{ mv/°F} \times T$$

Where

- V_{OUT} is the LM35 output voltage
- T is the temperature in °C which is then converted to °F.

VIII. SYSTEM USAGE ANALYSIS

A. *Primary Stakeholders*

Primary stakeholders are those who directly interact with the system. The primary stakeholders are: The Doctor, Web Administrator and the Patients.

B. *Secondary Stakeholders*

Secondary stakeholders are those who are not directly interacted with the system but receive output. In our system the secondary stakeholders are the people doing surveys, government officials and the senior doctors.

IX. RESULTS & DISCUSSIONS

The patient registration is important to create or access the previous records/history and to check the new readings of vital signs. Patient's details are stored as shown in figure.

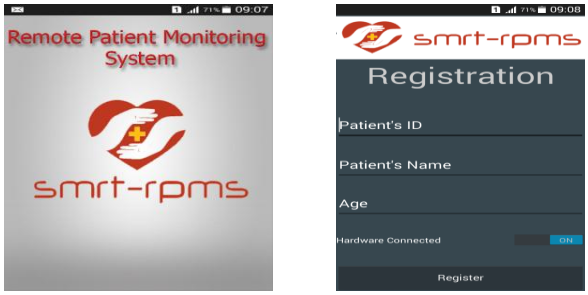

Fig. 11. Smrt-rpms-App title screen &Smrt-rpms-App registration

After the registration process patient has to select the concerned specialist which are available in the displayed list as shown in figure.

Fig. 12. Available doctors list &Selected doctor

The option menu then appeared for the selection of desired parameters, as shown in figure.

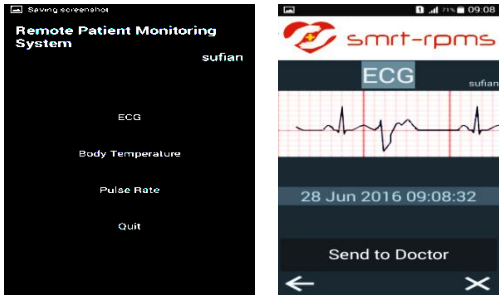

Fig. 13. Option Menu & ECG test of subject

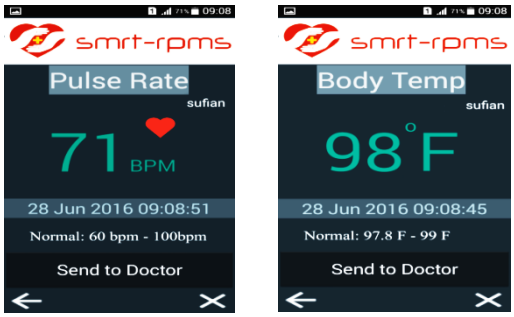

Fig. 14. Pulse Rate & Body Temperature

X. CONCLUSION

In this paper, we presented a real time monitoring system named '*Smrt-rpms-app*' it incorporated two currently revolutionary technologies wireless sensor networks and mobile network technology. *Smrt-rpms-app*develops reports about the patient's information to enhance the patient-doctor interaction remotely. The report or record is consist of ECG, body temperature and pulse rate. Whenever the patient data or signals are transmitted to the doctor or concerned person through the mobile app then the *Smrt-rpms-app* system provide facility to doctors to give prescription online/remotely.This system also provides the facility to store the patient history which reduces the documentation load of doctors also to predict the patient's health before and after the diagnosis. In countries like Pakistan where there is limited number of hospitals, there is a huge patient rate visit to hospitals. In such cases the hospitals are less to accommodate the patients and also there is not enough medical staff to handle the patients. Same time the hospitals are not so equipped technologically to remotely monitor the patients instead they are still using handwritten reports. The increased rate of patients has reduced the functioning of staff. So, consequently, we may say the *Smrt-rpms-app* is definitely a future trend in clinical medicine, an option to improve treatment operations & a solution to provide patients to approach limited number of professional doctors.

XI. ACKNOWLEDGEMENT

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