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Research Article,

Smart Connectivity with Patients (SCP): A Practical Approach

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Abstract: Diseases like cardiac, increase/ decrease pulse rate, sugar and blood pressure are becoming major cause of life failure during this era even youth is under the attack of these diseases. These diseases are of permanent nature and the patient suffering with this disease required a great care of their health by properly and continuously monitoring the vital sign and incase of crossing threshold values can take the appropriate measures. The continuously monitoring is not an easy task especially struggling hours, such as travelling, offices, having heavy meal, running/ jogging etc., and these hours can be more critical than normal hours. To avoid the critical condition in these timing the best way is to instantly warn the patient about the vital sign and incase of crossing the threshold values the patient, his beloved and rescue centers have to inform along with patient's geographical location. Thanks to the availability of low-cost sensing devices, ambient intelligence (AmI) and 3G/4G technologies which provide a help to achieve these objectives in an automatic way. This paper will discuss a smart technique for patient connectivity, within our limited resources. We are going to discuss introduction and literature review in section 1, materials and methods in section 2, results and discussion in section 3, and finally, results will conclude and will also discuss present and future challenges in this domain in section 4.

Keywords: Real-Time Monitoring; Smart Patients Monitoring; Smart Health Monitoring;

1. Introduction and Literature Review

Patients can be classified into two groups, permanent diseased and temporary diseased patients. Temporary diseased patients may be categorized as such patients who are facing their disease temporarily means they may recover soon or later and have no need of continuous monitoring on regular bases. Permanent diseased patients are those who are facing their diseases permanently/ long-lasting i.e. cardiac, increase/ decrease pulse rate etc., and they have to face and need to control those diseases on regular basis.

Permanent diseased patients are growing rapidly; even youth is under the attack of these diseases, patient suffering from these diseases cannot bear negligence of their health condition and required a great care of their health by properly and continuously monitoring as they could not suspend their daily life routine e.g. they have to travel, have to perform their duties and other activities in a caring mode because it is human physiology that people want to complete their tasks first and then have to rest, even they were feeling uncomforted e.g. facing high blood pressure while driving, feeling cardiac pain while walking/ jogging and

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moreover in some cases cardiac pain is not feel by the patient but its incurred. Little negligent in these vital sign measures can be the reason of any critical condition for the patients. Ischaemic heart disease and stroke are the world's biggest killers, World Health Organization (WHO) categorized top 10 causes of death globally in 2015, and enlisted heart diseases is responsible for 13% of the world's total death, even more death then in COVID-19 pandemic, while heat disease is noncommunicable disease [17].

To overcome these issues, it is required to have a continuously monitoring of patients' vital signs with accordance to their diseases which is challenge and in case of crossing the threshold values to intimate the patient, surrounding people, family members and the doctor with the geographical location is a concerning task for indoor and outdoor premises, but it will helpful for avoiding any criticality.

Bio-sensors can be helpful for obtaining this vital sign, depending upon their functionality and covered sign measure. According to the disease and the bio-sensors covering features one or more bio-sensors may attached with the body of patients. These bio-sensors can be in the form of some decent hand-band, smart bio-sensed watches or something having sophisticated feel and look. The bio-sensors are of heterogeneous nature and provide facility to measure some specific sign. Some of them provide the functionality to transmit the measured data into some specified protocol. First of all, it is important to know from which device the data is coming. Then accordingly parse the packets and identify the relevant data. The obtained data is further required to transmit on the Online Server by using some communication standards (i.e. WLAN, GSM, GPRS, UMTS and WiMAX etc.) on server services these vital measures are uploaded and saved with accordance to specific patient with holding time and other important information. Where the values are analyzed and incase of crossing any threshold value the alarming strategies are invoked, can be a SMS/ call to the patient, their attendants, doctors or a voice message to the patients and nearby people to take care of them (patients). Moreover, the recorded patient data can be used by the doctors for knowing the patient's history, with permission of patients.

Continuously monitoring of patient is an important research area, in which different bio-sensors are being designed, developed and integrated with the existing daily personal use, devices (e.g. watches or decent arm-bands), garments (i.e. clothes or gloves, belts, shoes) or implanted (i.e. pacemaker or cochlear implant) into the patient's body. Wearable sensors, generally, refer to sensors that are positioned directly or indirectly on human body; they generate signals when the user performs activities [2]. Wearable sensor technology continues to advance and provide significant opportunities for improving personalized healthcare [19].

Wearable sensor systems are progressively becoming less obtrusive and more powerful, permitting monitoring of patients for longer periods in their normal environment. Current commercially available systems are compact, enclosed in durable packaging, and utilize either porTab. local storage or low power radios to transmit data to remote servers [20], [21], [27], a comparison of some wearable smart watches are shown in Table. 1.

Many large technologically established companies, such as Google, Microsoft and Phillips are now focusing and introducing their innovated wearable bio-sensor based products into the market, and it is assumed a profiTab. business. The field of designing and developing bio-sensor trend is speedily increasing, due to their small sizes and continuous monitoring of the patients benefits.

On positive side, directly or indirectly, these smart watches could communicate and able to send messages, but lot of these watches are costly and has limited built-in sensor features, most of them have heart pulse sensor, on the other hand temperature, humidity, ECG sensor and other important sensors are missing which are important for patient's monitoring especially with Ischaemic heart disease.

These devices are capable of transmitting the data by using some wired or wireless technologies. The wireless technologies normally transmit the data, for the short range (such as body area network (BAN), Bluetooth (IEEE 802.15.1), ZigBee (IEEE 802.15.4), 'intra-BAN communication include infrared' (IrDA) the medical implant communication service (MICS), body sensor network (BSN), and ultrawideband (UWB).) and in some cases for the wider range (WLAN, GSM, GPRS, UMTS and WiMAX) [25], [26].

Table 1: A comparison of some wearable smart watches. ~ Approximately

Features	**Exmovere Empath 2.0**	**Apple Watch Series 3**	**Garmin Forerunner 735XT**	**LG Watch Sport**	**Polar M600**	**LEMFO LEM6 IP67**	**NO.1 G8 MT2502**
Image							
			DESCRIPTION				
Weight	74g		40g				62g
Display (**description**)	Multicolor OLED, 1.8”	Multicolor, (312 x 390 pixels), 1.66”	Multicolor, 1.2”	Multicolor, (480 x 480 pixels), 1.37”	Multicolor, (240 x 240 pixels), 1.3”	Multicolor, (400 x 400 pixels), 1.4”	Multicolor, (240 x 240 pixels), 1.3”
SiM Card	Yes		No			Yes	Yes
Make Call	Yes	Yes		Yes			Yes
SMS	Yes	Yes		Yes		Yes	Yes
Batter Life (Standby)	Up to 64 hours	Up to 24 hours	Up to 264 hours		Up to 24 hours		Up to 72 hours
Bluetooth	3.0	4.2	No	4.2	Yes	Yes	4.0
			BUILT-IN SENSOR FEATURE				
Pulse Rate Sensor	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Temperature Sensor	Yes	**No**	**No**	**No**	**No**	**No**	**No**
Humidity Sensor	Yes	**No**	**No**	**No**	**No**	**No**	**No**
GPS Sensor/ Positioning	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ECG Sensor	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Pedometer	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Stop watch	Yes	Yes	Yes	Yes	Yes		
Speed Display	Yes	Yes	Yes	Yes	Yes	Yes	
Alarm	Yes	Yes		Yes			Yes
			ACCESSORIES				
Heart rate strap	Yes						
Pedometer device	No need	No need	No need	No need	No need	No need	No need
GPS device	No need	No need	No need	No need	No need	No need	No need
Temperature device	No need	No need	No need	No need	No need	No need	No need
Smart phone	Yes	Yes	Yes	Yes	Yes	Yes	Yes
			Retail Price				
MSRP in US	~ $299	~ $429.0	~ $497.2			~ $121	~ $50

Surveys papers [6], [10] related to communication technologies discussed communication protocol and standards. Data collected through short-rang technologies can be further transmitted at wider range using other technologies and devices (smart phone etc.); comparison is shown in Table 2.

Table 2: IEEE Communication Protocols [6], [10]

Parameter / Standard	Application	Bandwidth (MHz)	Data Rate/ Throughputs	Max Range	Network Topology
Bluetooth IEEE 802.15.1	Wireless Sensors, (Monitoring & Control)	2.4 GHz	1 Mbps – 3 Mbps	~10m	Star
Infrared intra-BAN communication include infrared (IrDA)	Short-range communication	115.2 kbps - 14 Mbps	16 Mbps	100m	
Li-fi[18] IEEE 802.15.7	operation theaters, data transfer, internet browsing	10 thousand times frequency spectrum of the radio (100 X Tera HZ)	1+ Gbps	~10m or less	Peer-to-Peer, Star, Broadcast
UWB Ultra-Wideband IEEE 802.15.3	Multimedia link	3.1 – 10.6 GHz	110 – 200 Mbps	~10m	
Wi-fi IEEE 802.11 WLAN	PC based Data acquisition, Smartphone Internet	2.4, 3.7, and 5 GHz	1 Mbps – 450 Mbps	5000 m	Star, Tree, P2P (Various Topologies)
WiMax IEEE 802.11 WWAN	Smartphone Internet	2.3, 2.5, and 3.5 GHz	75 Mbps	1500 m	Star, Tree, P2P
ZigBee IEEE 802.15.4	Wireless Sensors, (Monitoring & Control)	2.4 GHz	250-500 kbps	100 m	Cluster, Mesh, Star, Trees

Many researchers are working on activity-based monitoring and developing innovative solutions, related sensor-based activity reorganization. Liming et al. [2] classified sensor and activity monitoring into two main categories in terms of the way they are deployed in activity monitoring applications, Wearable Sensor-Based Activity Monitoring and Dense Sensing-Based Activity Monitoring. Alexandros et al. [7] presented a physiological data fusion methodology that is applicable to WHMSs (Wearable Health-Monitoring

System for People at Risk) and defined a novel model based on fuzzy regular formal language to describe the current state of health of the WHMS user. Figueiredo et al. [8] designed low power wireless acquisition module as a solution for WHMS, they designed their own PCB as prototype of the wireless acquisition module, which they divided into 4 parts wireless link, single-lead ECG monitoring, activity and temperature monitoring and power supply section. Young-Dong et al. [9] purposed a smart shirt a wearable solution for encounter physiological and physical activity. Smart shirt holding wearable sensor node (using a sensor board), using wireless communication IEEE 802.15.4 through multi-hop network nodes are communicating to base station and to server PC where doctor can visualize the patient data.

Several recent studies [1], [11], [12] discussed health monitoring system within hospital premises, where Pietrabissa et al. [1] presented an optimization framework for planning of a sensor network in hospital environment, using statistical model, technology-dependent sensor model and formulation of the optimal planning problem as a binary (linear) programming problem. Several recent studied [3], [4], [5] discussed health monitoring within home premises, using wearable sensor and distributed EHCR database e-health model based on IoT, and discussed different IoT protocol over Internet protocol. Sergio et al. [3] present a healthcare monitoring system of convalescing patients at home based on WBASNs (wireless body area sensor networks) and multiple channel usage for improving system capacity.

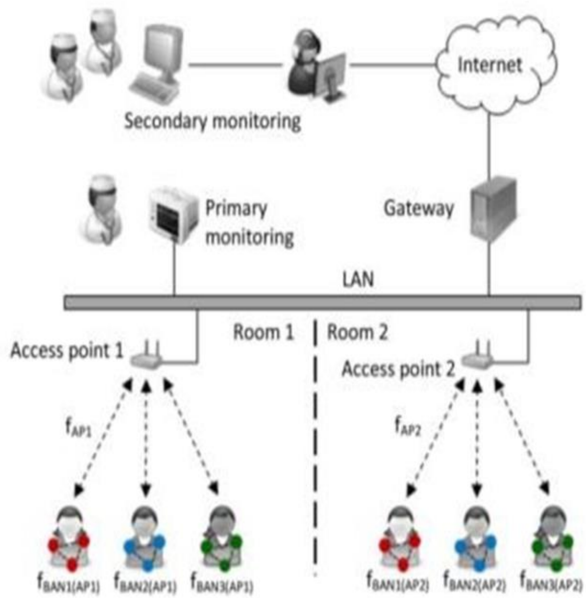

Figure 1: Proposed System Architecture [3]

Some researchers also used other technologies for emergency monitoring for health propose such as RFID [14], [16].

Figure 2: RFID Architecture [16]

G. Tia, et al. [15] discussed vital signs monitoring and patient tracking over a wireless network, used Vitalmote sensors (Vitalmote sensors are porTab. lightweight electronic triage tags that are designated by paramedics with red/ yellow/ green/ black lights based on the severity of the patient's condition) and a website-based solution for emergency monitoring. They communally considerable bio-signals related to measure the sign are electrocardiogram (ECG), body and/or skin temperature, heart rate, and body movements etc., which can be measured by the respective bio-sensors whose have the capabilities to recognize them.

Various researchers are working on designing and development of these wireless sensor network, whereas some are working to integrate these bio-sensor technologies with the existing technologies and provides smart linkage [9], [15].

In many discussed applications authors did design their own hardware and sensors which have their limitation in measuring capacity and limited bio-sensor features. Most authors did focus just for indoor solution (i.e. hospital, home premises etc.) or just for outdoor solution. Whereas the proposed research aim to develop an independent environment from specific company to capture all the vital sign (if one bio-sensor is not sufficient then add others to measure the remaining features from different companies) and accordingly the proposed research will provide the facility to send an alerts without limiting to a short (or few KM) transmission range and a central system which will interconnect patients with emergency department and hospital and it will application for both indoor and outdoor premises.

2. Materials and Methods

An overview of the proposed research in this paper is graphically elaborating in Fig. 2-1. exploring the activities as follows

1. Using biosensors (watches/ different sensors) patients are under continuous monitoring even if they are walking/ exercising, at home/ office, during travelling and in hospital. Embedded hardware module (Arduino board) is used with bio-sensors
2. which is reading vital sign of patient. Smart phones/ smart devices are used for communication purpose along with hardware module and server. GPS/GPRS services is also important, which could be used using separate module or by using smart phone, to communicate the geographical location of patient. In general, emergency is assumed can notified using software solution designed specifically to handle respective cases of emergencies as per purposed system in following cases if
   - a bio-sensor readings/value is crossing threshold level,
   - an accident or emergency is occurred with patient or/ and emergency request could send a 'self-emergency request' by using smartphone.
     - ➢ When an alarm strategy is invoked that will inform the surrounding peoples about emergency and alert to the attendants/ family members will also invoke.
     - ➢ Initially, bio-sensor data could store on Arduino board using different storage or could store on smartphone optionally. With the help of smartphone alert will sent to the concern people and rescue department.
3. By adopting different or suiTab. communication protocol, and communication mediums (3G/ 4G) data will transmit on data server, and could be retrieved from server using same medium.
4. A medical history of patient will part of record, stored on server. Bio-sensor data could store completely or partially in smartphone storage and on server, as per convenience. On server, different calculations and computation will perform and results/ information can display further.
5. Accordingly, intimation will communicate with 'Rescue department', 'Health department', and with 'family members' about the patient situation & patient information (location etc.). In addition, these 'Rescue department', 'Health department' and 'family members can communicate to patients and will play an active role to secure/ cure the patient. Where 'Rescue department' and 'Health department' could also retrieve data from server.

2.1. Hardware Materials

Following hardware components and including smart phones are used to implement the project with minimum requirements.

2.1.1. Smart Embedded Board (SEB)

SEB is main hardware component used for setup SCP system, where all other components/ sensors (which are attached with patient body) and devices (Bluetooth module etc.) is connected with it, means it`s just works as motherboard where all hardware components are being plugged. Arduino Mega 2560, Raspberry pi 3 (model B), Orange Pi Plus, and BPI-M64 etc. are commercially available SEB in market. Each company is designing their board to compete others competitors with race of cost-effectiveness and distinguish features.

We used Arduino Mega 2560 (shown Fig. 2.2 (a)) as it is meeting all minimum requirements for SCP environment to be implemented. SEB is programmable hardware component; Arduino IDE is the open-source Arduino software to write code and upload that code on Arduino board.

Microcontroller and Other Technical Specification

Arduino Mega 2560 is enough to meet our all-minimum requirements, holding ATmega2560 processor that is single clock processor, designed to achieve a throughput approaching 1-MIPS per MHz.

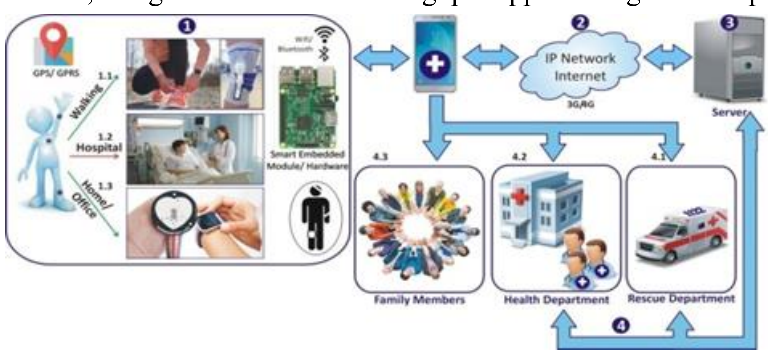

Figure 3: Graphical Presentation of Proposed Methodology

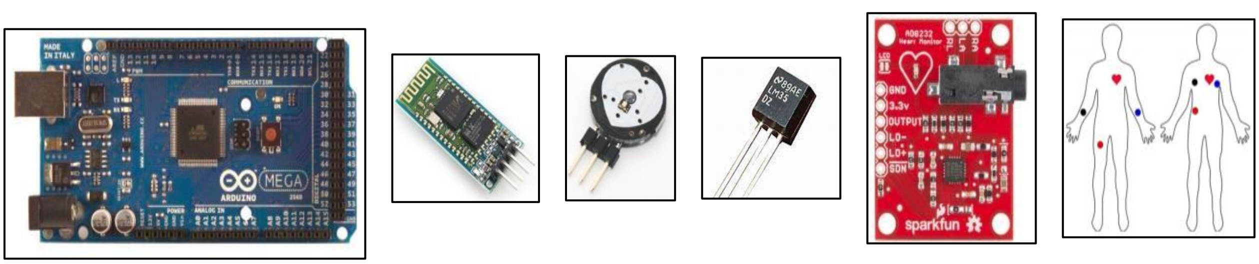

Figure 4: (a) Arduino Mega 2560, (b) Wireless Bluetooth Module, (c) Heart Beat Pulse Sensor, (d) LM35 Temperature Sensor, (e) AD8232 ECG Module and (f) Electrode Placement

2.1.2. Bluetooth Module

"HC-06 RF Wireless Bluetooth Module" (shown Fig. 2.2 (b)) is industrial standard transceiver slave module, and it doesn't require any external antenna for data communication. Its sensitivity characteristic is quite good; EDR module whose range of modulation depth is 2Mbps – to- 3Mbps, modulation frequency 2.4GHz, small size (27mm × 13mm × 2mm) and can perform its task at low voltage range [22].

2.1.3. Heart Beat Pulse Sensor

Heartbeat pulse sensor (shown Fig. 2.2 (c)) is easy to use with prescribed Arduino module, clip-able on patient's earlobe and fingertip. Its best operating voltage range is about +3V to +5V, it can be used to calculate heart beat in form of beats per minute (BPM), check time between heartbeat the heart rate variability (HRV), and output data can be graphically displayed as heartbeat waveform, which make its importance to be used.

2.1.4. Temperature Sensor

The LM35 (shown Fig. 2.2 (b)) series are precision integrated circuit temperature devices with an output voltage, which is linearly proportional to Celsius temperature (can be further converted to Fahrenheit), used for calculate patient body temperature. It is preferred as because of its characteristics and specification as it is low power consuming, small in size, providing ±¼°C accuracy in temperature at room temperature and ±¾°C accuracy over a full −55°C to 150°C temperature range [24].

2.1.5. Electrocardiogram (ECG) Sensor

AD8232 sensor (shown Fig. 2.2 (e)) is used for ECG monitoring it shows analog output; output voltages could be further charted as ECG value and can be chart as ECG graph. It consists on three electrodes (left (LE), right (RE), and common electrode (CE)), and it holds its own microcontroller & module and compatible with Arduino module. It can perform it functionality at low voltage as 3.3V, having small in size make it good choice; while taking measurement it is advised to patient not be in moving position. Preferably, LE and RE attached left and right side to heart position of human (as close to the heart is more advised for more accurate results) and common electrode (CE) is attached somewhere below to the chest, abdominal position or at thigh of right leg, typical electrode placement is shown Fig. 2.2 (f)[27].

2.2. SCP Application Solution

SCP software solutions purposed different modules 1) Permanent diseased patients' solution, 2) Rescue emergency management system solution, 3) Health department solution and the 4) Server's hosts.

We can refer SCP system by a 5 tuple as mentioned below:

$$SCP = (P, E, H, S, C) \tag{1}$$

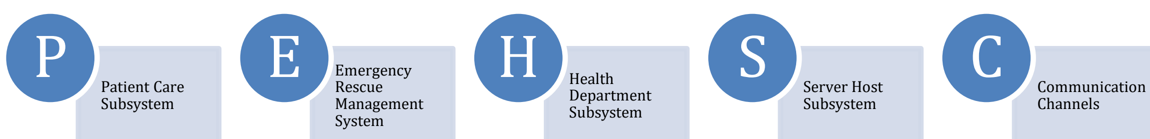

Figure 5: SCP System Components

2.2.1. Permanent Diseased Patients Solution (Patient-Care)

Patient-Care is an android-based smartphone solution running for permanent patients, to continuously monitoring. Patient-Care is integrated with different bio-sensors heart beat pulse sensor, temperature sensor, and ECG sensor, using embedded board (Arduino Mega 2560), targeting for automated task performing and alert invoke operation.

Patient-Care provides vital sign information to patient, to monitor their health status. Patient could add, remove and edit/ update the contact numbers which they are willing to be instant warned along with geographical location as in case of emergency occurring, bio-sensor value is crossing the threshold value.

As bio-sensors data is being collected and initially stored on smartphone, a data uploading daemon runs as a background process, not being under direct control of an interactive patient (user) and connected to the central server, and uploading bio-sensors data expediently.

Uploading Bio-Sensor Data Continuously

Patient-Care is designed to monitoring & uploading data continuously and to prevent date error, and data losses, we implemented many checkpoint states. First, it checks either communication device (Bluetooth) is ready or not, then collect the bio-sensors data and check either data is coming as per expected pattern or not, if any error found it will stop working and will notify the patient. Secondly, uploading daemon may stop uploading bio-sensor data to the central server depending on internet connection status, and will retry uploading biosensor data as on re-establishment internet connection, and in case of slow internet connection remaining bio-sensor data will remain stored in smartphone to be uploaded, such connection problems can probably delay in uploading bio-sensors data but will not reason of data lost.

2.2.2. Emergency Rescue Management System (ERMS)

Emergency Rescue Management System (ERMS) is an android-based smartphone solution designed for patients and for rescue department management. Using ERMS users may register themselves, provide their emergency contacts, using that contact numbers in case of emergency a self-emergency request along with his geographical location (using GPS/ GPRS service) can be also send to respective rescue department and family members simultaneously.

Rescue department and family members will receive emergency request and could instantly contact and trace the patient using ERS and Google maps. ERMS provides different domains for health department to receive separate emergency request i.e. road accident, fire emergency, and natural disaster.

The modeling of a Patient Care subsystem can be done by a 5 tuple as mentioned below:

$$P = (X_p,\ U_p, Y_p, \delta_p, x_p^0) \tag{2}$$

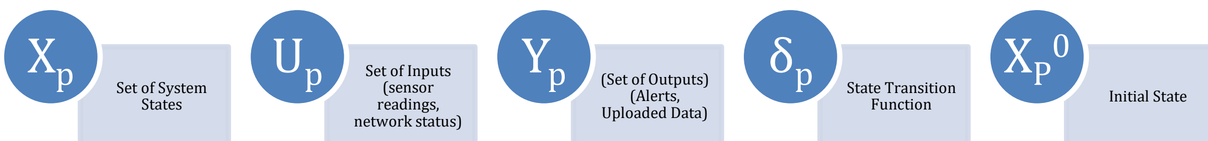

Figure 6: Patient Care subsystem Components

2.2.3. Health Department Solution

Health department solution is a web-based solution designed for health department for retrieve sensors data through server services, a visual presentation, and to check patient history. Front-end represented by using JQuery/ CSS/ HTML, middle tire ASP.NET (MVC) & C# and backend tire using SQL database etc., compatible for smartphone to be accessed through web browser.

The modeling of Health Department Subsystem could be done by a 2-tuple as mentioned below:

$$H = (Q, R) \tag{3}$$

Figure 7: Health Department Sub-System Components

2.2.4. Server's Host

Data server and web servers are used. Server service is used to provide a central location for storing, retrieving and maintaining the bio-sensor data and emergency requests data. Using secure channels permanent diseased patients, rescue emergency management system and health department software clients can coordinate data from data server and web server, and a live data forwarding service to perform background data services. Different network services run on server to perform operations. The bio-sensor background uploading daemon service provides the facility to store the bio-sensor data continuously on server. The web server provides access to stored data and retrieves the biosensor data. Background logging service and background services to performing logging service are used to perform live rescue process.

$$S = (D, L, F) \tag{4}$$

Figure 8: Server Host Components

3. Results and Discussion

We successfully designed and implemented our project which validates all the designed rules and suggested methodology. SCP software solution consists of two major modules, Patient-Care and ERMS and we designed a console for health department for patients live monitoring including all vital signs. In case of emergency, emergency messages through SMS and SCP software solution notification are successfully send to health department, rescue department and family members. Patient having SCP hardware solution, sensors are clipped on body, frequently monitoring their vital sign using Patient-Care solution, in case of emergency (crossing threshold value) alarm, SMS and/or SCP software solution-based notification strategy is performed.

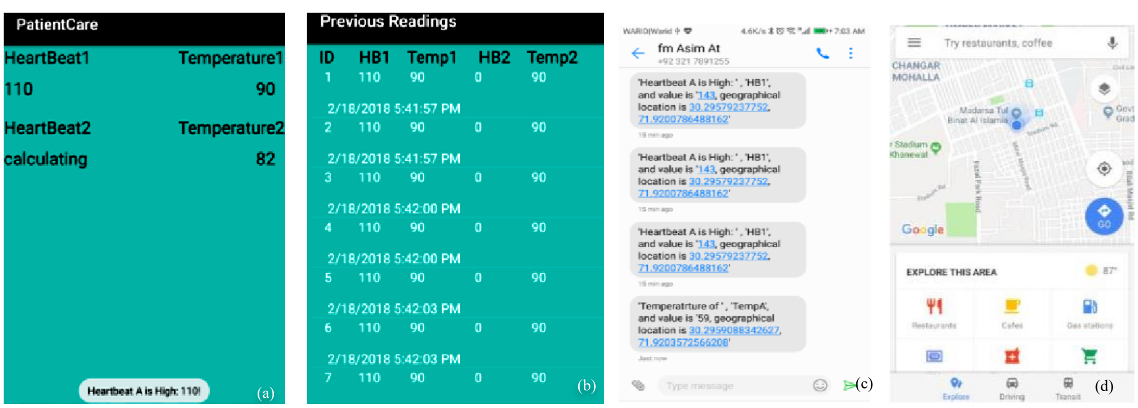

Figure 9: (a) Sensors live reading, (b) Previous readings, (c) SMS alert with Latitude & longitude, (d) Navigation using Google maps.

- Patient's live vital sign readings are being monitored, sensors are showing different readings. An alert is also displaying on screen as "Heartbeat A is high" as heartbeat sensor value is crossed its thresh hold value, meanwhile using emergency contact numbers SMS alert is being sent, and data is stored on smartphone memory and send to the server by the SCP system.

- Showing previous sensors reading.
- Emergency alert to family members is received along with patient's geographical location, specific vital sign crossing the threshold value.
- Emergency alert receiver could trace patient using Google map.
- *Health department* may monitor the patents and could look all their vital signs which were uploaded using Patient-Care.

Figure 10: Health Department Console

- If a rescue service is needed as emergency occurred (e.g. in the case of road accident, fire situation, any natural disaster, earth quake or patient's vital sign value crossing its threshold value etc.) rescue needed for himself or for someone else using ERMS solution emergency alerts are sent to the 'Rescue Department'.

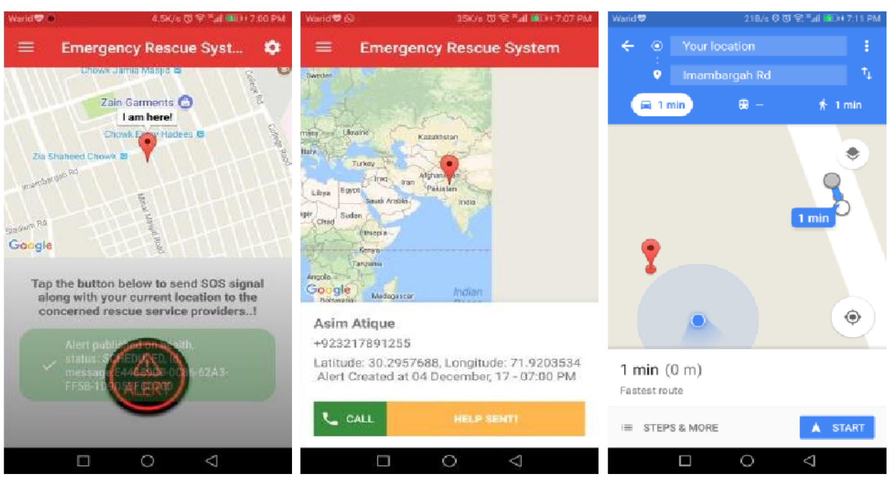

Figure 11: (a) Emergency Alert sent to Rescue Department, (b) Rescue Department Responding the Emergency, (c) Navigating the Patient

- Emergency alert sent to rescue department.
- After receiving rescue request, rescue department administration responding the patient using Google Map service.
- Live navigation.

4. Conclusion

We successfully designed and tested Smart Connectivity with Patients system, alert messages were invoked with both cases; as using Patientcare solution, bio-sensor based automatic alert (in case of any value is crossing the threshold value) and using ERMS solution-based alert (in case of emergency is occurring i.e. road accident, fire situation etc.). We tested in different scenario and evaluated the system and found that The SCP system guarantees continuous monitoring without data loss under intermittent network conditions.

On the other hand, many issues needed to be addressed as suiTab. selection, quality, and method of attachment of sensors and devices are quite important. As smartphone is used for obtaining GPS/GPRS based patient geographical location, have accuracy issue and errors mostly expected this error varies depending upon smartphone devices. Internet speed and connectivity with server has always impact on performance, especially for uploading and fetching ECG data which is always bulk in amount.

Same wise sensors clipping/ placement on patient body and patient body position (e.g. it is advised to be in rest position while ECG sensor taking reading) is influencing on bio-sensors reading.

5. Future Work

Our future work is to make operations with better performance and with more efficiency, and to find out solution to overcome issues discussed in this research paper. We are also looking for work to find out the practical approaches for non-invasive blood pressure (BP) and blood glucose level calculation solution through the means of software and hardware-based solution.

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Conflicts of Interest: Authors have no such conflicts.

Data Availability: Data used in this paper is not available publicly.

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