



Mobile-Phone -Based Remote Patient's Vital Signs Monitoring and Automated Alerts

¹Fareed ud din, ²Atta-ur-Rehman Shah, ²Muhammad Ibrahim

¹ Superior University, Lahore, Pakistan

² Hashe Computers, Lahore, Pakistan

Abstract

This paper focuses on Mobile-Phone-based Remote Patient's Vital Signs Monitoring and Intelligent Alerts System which, using pervasive technologies simplifies the human life by automated functioning of medical sensor devices and an intelligent data record system with validation and transmission of health tips to the patients as well as to the guardians. The proposed system consists on different components which automatically perform patient's vital signs monitoring (e.g. body temperature, heart-rate, breathing rate, activity and posture) and carry out remedial actions in emergency condition (e.g. medicine dose tips, precautions alert to patient, alert to hospital staff in emergency conditions etc) as well as directly from the specialists to the patients on their mobile-phones as the proposed system include a mobile application as well. In order to achieve the robustness in examining the patients remotely, the system will provide the real time intelligent Content Management System(CMS), installed at respective hospital, capable of making intelligent decisions based on patient's medical status and information generated from patient side. A mobile (Android) application is also the part of the system to facilitate the patient to be examined with the mobility and to view the current conditions and the alerts generated automatically by the CMS as well as from the specialist. This system will not only deal the critical patients but also the normal persons (busy personnel's and traders or business) can take benefit to retain their health by subscribing to the proposed packages of Automated Tips and Alerts by the system. This system is also beneficial for specialists to monitor their patient remotely via mobile application.

Keywords: Patient Monitoring (RPM); Vital Signs (VS); Remedial Actions; Personal Digital Assistant (PDA); Automated Alerts

1. Introduction

The remote patient monitoring (RPM) is categorized as the sub-field of telemedicine where a patient is monitored remotely through communication technologies (e.g. www) by the medical staff. It is important to observe status of the patient's vital signs in real-time environment which web technology unfortunately is not seemed to fulfill [1]. Hence there is need of a technical solution which can play role to automatically perform patient monitoring and do remedial action in emergency condition (e.g. medicine dose, precautions, alert to hospital staff etc.). The Mobile Phone based Remote Patient's Vital Signs Monitoring provides number of benefits: reduce loss of life, automated working with less human interaction, facilitate villagers and chronically ill patients, vacant beds for emergency patients and so on.



In RPM environment, different roles are divided like medical staff (doctor and specialists), patients, non-medical staff (nurse ambulance driver) and guardian of the specialist. The application on patient location monitors continuously health status of the patient, working on a computer or a cellular device (Mobile-Phone). The patient's side module provides proactive care and notifies the patient or the guardian (as selected by the user) before happening emergency condition. Upon obtaining updated information (temperature, sugar, blood pressure and heart-rate thresholds), patient's module sends notification to doctor side module. The doctor's side module analyzes report based on historical data and may send it to specialist agent for later diagnosis. Thus, frequent visits to doctor are reduced considerably. Additionally, chronically-ill patients do not have to occupy hospital beds for long time, remaining available places for emergency patients.

Consequently, RPM may provide medical services in most populated villages where hospitals are not enough [2].

This paper provides a technical assay for RPM systems. Brief overview of the proposed RPM approach is discussed in Section 2. Related works are discussed in section 3 latterly. With this vision, we propose a framework in Section 4 while comparison among different approaches is given in Section 5. Then prototype system implemented on proposed concept is demonstrated in the Section 6. Finally Section 7 concludes the work and provides future directions.

2. Proposed Architecture

In remote patient monitoring (RPM) environment, there are different components that perform different roles like doctor, patient, specialist, and nurse. The sensors attached with the patient monitor continuously health status of the patient. The information will be sent to Medical Data Centre via Base Transceiver Station (BTS) for processing. The Medical Data Centre will provide proactive care and notifies the patient before happening emergency condition. Upon obtaining critical information (high temperature or increase in sugar level), the Medical Data Centre will inform the specialist via GSM services. The Medical Data Centre will analyze reports based on historical data and may send it to specialist for later diagnosis. Thus, frequent visits to doctor are reduced considerably. Additionally, chronically-ill patients do not have to occupy hospital beds for long time, remaining available places for emergency patients. Consequently, RPM may provide medical services in populated villages where hospitals are not enough. The RPM provides number of benefits: reduce loss of life, automated working with less human interaction, facilitate villagers and chronically ill patients, vacant beds for emergency patients and so on.

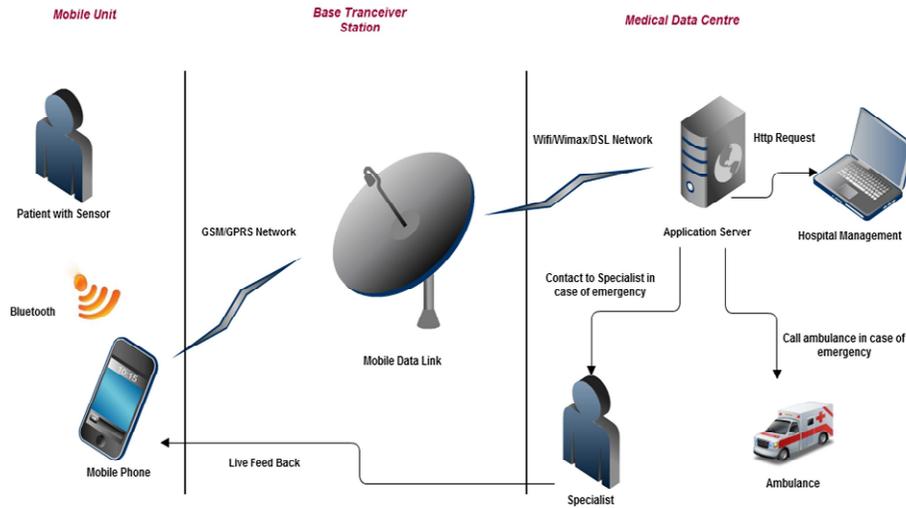


Figure 1: Schematic Architecture of Proposed RPM Network

The main concepts involved in the development of Mobile-base Remote Patient Monitoring System are following:

- *Mobile-Based Monitoring*

Since patients are being monitored through cellular application, we will use the term mobile-based monitoring. An android application will be developed to monitor chronically ill patients as well as normal patient.

- *Remote Patient Monitoring*

This concept is somewhat deeply rooted in the concept of telemedicine. Telemedicine is the field which eliminated the concept of in-housed monitoring of patients and makes it possible to monitor the patients using telecommunication methodologies.

- *Real Time Content Management System*

In the proposed system, a real time Content Management System will be developed which will be smart enough to automatically take decisions based on the data received as well as the previously stored information.

- *Health Maintenance for Normal People*

This system will also provide an opportunity to normal people to take of their health. They will be provided facility to remain in contact with main server through cellular application via GSM/GPRS.



3. State of the Art

In contrary to the video-based monitoring systems [2], the proposed system offers patients and specialists registration module to permanently adhere the users to the system and give automated alerts and tips to maintain the health status to the normal level. The proposed system is using a GSM modem to send the Alerts and Tips SMS to the patients as well as to the guardians. Plus this system works intelligently to send the address of the patient in emergency conditions to the ambulance driver as an emergency alert so that the ambulance can pick the patient before time. This system is using different threads for the parallel processing like the multi-agent based systems. This system is not only for the diabetic patients specifically and not only for the hypertensive patients [3] but it covers all the patients because it is monitoring all the vital signs of a patient which are necessary for specialist and physician to diagnose any disease.

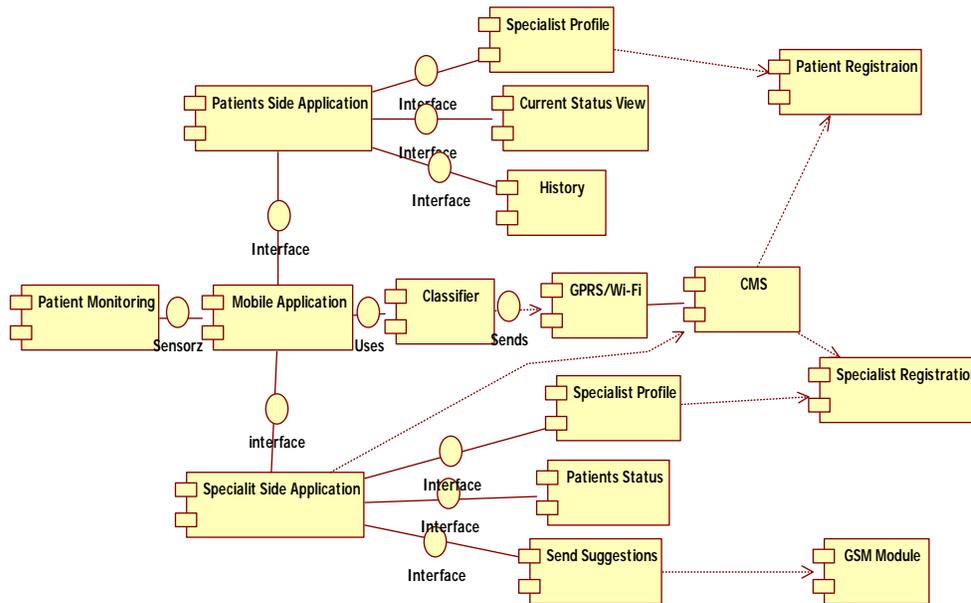
A detailed survey on a robust RPM environment highlights characteristics such as reusability, elasticity, consistency, robustness, flexibility, malleability and maintainability [4]. The Multiagent based system for collaborative scenario presented in the telemedicine field [5] is applied for patient appointment, where external specialist functions are implemented for doctor appointment [6]. In practical, the performance evaluation of the IEEE802.15.4/Zigbee in Wireless Body Area Network (WBAN) is elaborated in [7]. For diabetics patients, a Java based RPM is discussed in [8]. A rule-based RPM system is explained in [9] which receive data from a wireless sensing device at patient location. RPM systems always need to have previous trends to predict and to find the optimized threshold, the techniques to train the Knowledge-base (KB) are demonstrated in [10].

4. Method

The proposed environment, there are different components that perform different roles like doctor, patient, specialist, and guardian. The patient side module continuously monitors health status of the patient, working on a computer or a cellular device through wireless medium like Bluetooth using Sensor devices for measuring vital signs and send the monitoring values to the CMS via GPRS or Wi-Fi connection. [11] The patient's component provides proactive care and notifies the patient before happening emergency conditions like up-burst of heart-rate or breathing-rate. Upon obtaining updated information (high temperature or increase in sugar level), patient component sends report to doctor and patient records. The specialist component analyzes report based on historical data and may send it to specialist component for later diagnosis. Thus, frequent visits to doctor are reduced considerably. Additionally, chronically-ill patients do not have to occupy hospital beds for long time, remaining available places for emergency-condition patients [12]. Consequently, the proposed Mobile-Phone Based RPM may provide medical services in populated villages where hospitals and medical facilities are not enough.

In general, the issue in managing memory is the small capacity of mobile phones. It is necessary to keep each element of data in presence of huge data rates. For Huge data streams there must be fast, efficient, multiple, continuous and time-varying characteristics [13]. To manage small memory in data processing, approximation technique are very efficient for a robust environment they are discussed in [14, 16] that summarize huge data into compact form such that small memory can hold it in any data rate. A data streams management framework proposed in data warehousing domain [15] is focused on approximation and memory management. For and elegant interface layout and consistency on mobile device, application pattern of interface is necessary as the proposed application use Model View Controller (MVC) framework. This design pattern is encapsulated solution for increasing consistency in software development. Mostly, it is used in software architecture development, combining multiple standards. Patterns for cross-platform development of web applications are

proposed in [17]. Pattern approach for information visualization is presented in [16]. The Component Diagram of the m-RPM environment is shown below in Figure 2.



5. Unique Points

The records of the patients are very critical because they involve the life risk, pertaining health on stake. So if any of the records get missed then it means a loss of health resulting in mortality. So the proposed system is offering a local memory storage so that if there is any chance to disconnection of the medium of transmission then the data is stored in the local memory of the system (e.g. mobile-phone) So whenever the connection get stabled then the batch will the sent to the CMS and will be get stored in the system, this is the feature is not focused by any of the system developed recently. This system is classifying the data using Naïve Bayes theorem, which is also a unique feature of the proposed system.

Mobility: The proposed system is the system should keep running always, regardless of location as this includes a mobile-phone application too with a web application. It should not constrain to fixed location. The threads running on mobile-phone module are its example.

Security: The whole system must be centrally and efficiently controlled. Each entity must be authenticated before any further processing, its authorization before interaction which is made sure by implementing the development architecture with a tier based structure (Model View Controller-MVC).

Recovery: The system should not stop in case of failure of any component. The proposed system does have the controllers in order to enhance the capability to recover from the problem.

Efficient communication: The information from sending entity should be reached instantly to the receiving entity. The proposed system maintains the efficient and easy communication.



Updated technologies: The proposed system has the ability to work with newer technologies such as Bluetooth instead of infrared or Zigbee [7].

Centralized Database: The information in the tele-medical domain must be integrated and consistent in the presence of multiple modules working in the environment. A centralized database provides integrity of data which is maintained on a remote server.

Co-operation: The e-health environment should be accessible in which each module can easily co-operate and communicate with the other entities involving in it. The applications developed for the proposed system are both easily accessible and co-operative.

Failure Backup: m-RPM the proposed system is incorporating the backup for the failure as this proposed system is using the continuous GPRS/Wi-Fi/Internet connectivity but if there is no global connection available for the data transmission then the vital signs monitoring must not be discarded., they are stored in the local memory and whenever the connection gets available the batch is sent there and then.

Table 1: Comparison with Traditional Systems

Sr. No.	Features/System	Traditional	m-RPM
I	Mobility	NO	YES
II	Security	YES	YES
III	Recovery	YES	YES
IV	Efficient Communication	NO	YES
V	Updated Technologies	PARTIAL	YES
VI	Centralized DB	YES	YES
VII	Co-operation	PARTIAL	YES
VIII	Vital Signs Monitoring	NO	YES
IX	Failure Backup	NO	YES

Table 1 shows that Mobile Based Remote Patient's Vital

Signs Monitoring System (m-RPM) is being incorporated with the features which the traditional systems were previously lacking. Hence the systems enhance the capability of the system to runtime cooperate with the patient as well as the doctors and medical staff side modules.



6. Prototype Application

As per the earlier discussion a system is developed both on the hospital side (web and cell phone) and on patient side (web and cell phone). The Body Area Network (BAN) includes the non-intrusive wearable body sensors continuously monitor vital signs (blood pressure, blood sugar, body temperature and postures) and send the data through the Bluetooth to the patient side module in the cell phone. The patient side module performs analysis on the current data and instantly informs the patient and the medical staff in hospital in emergency conditions. It alarms the patient with information shown in Figure 3.

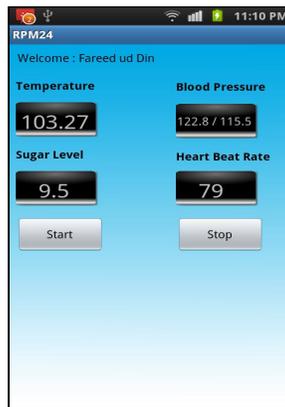


Figure 3: Patient's Vital Signs Monitoring Screen

Historic and previous records of the patients are recorded with the details. The proposed m-RPM provide the options for the user to view the graphical analysis of the earlier records in the forms of elegant graphs as shown in the figure 4 blow:

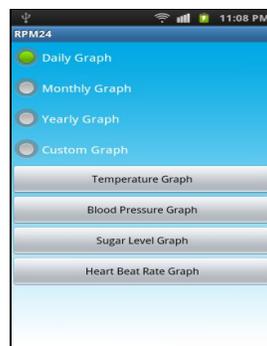


Figure 4: Graph Selecting Screen

After picking the desired option form the patient side module the desired graph and the view is as follows represented in the following figure 5.

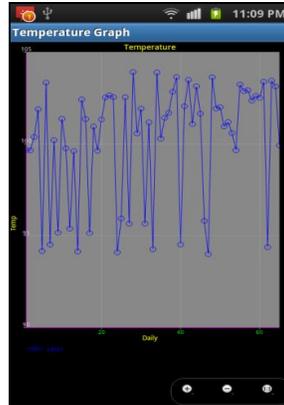


Figure 5: Graphical Analysis of Patient's Temperature Records

Doctor's side module is also incorporated with the security as well as different screen with the rights dissemination. After the username and login verification for the doctors can log in to their respective module for the processing.



Figure 6: Doctor's side home screen

Screen shown in the figure 6 includes the all the options for a specialist to go either view the notification for his patients or to suggest them. In this way the doctors can stay updated by the current status of his patient.

7. Conclusion

This paper is technical note on the system developed for the patient's vital signs monitoring with different user roles like patients, guardians, specialists, medical and non-medical staff providing all the users with the ease of access and mobility with robust functionality. Definitely this system is not the perfect one it left a lot of the



questions unanswered as because of the field of the bio-medication and e-health is too vast and it is very complex to incorporate all the issues occurring in between. Currently, Remote Patient Monitoring (RPM) systems are in growing phase and require maturity in different areas (e.g. alternative to continuous GPRS connection, battery life of nomadic devices and data management in the network, etc.) [4]. Classification techniques must be more shaper in terms of precision and accuracy. Classification techniques like A-Priori, and advance level of Naïve Bayes theorems for the missing value imputation and classification of critical data using data mining and artificial intelligence concepts.

References

1. V. Chan, P. Ray and N. Parameswaran, "Mobile e-Health monitoring: an agent-based approach", *IET Communications.*, pp. 223-230, 2008.
2. António Santos, Rui Castro, João Sousa, *Carebox: A Complete TV-Based Solution for Remote Patient Monitoring and Care*, *Wireless Mobile Communication and Healthcare, Social informatics and Telecommunications Engineering*, volume 61, 2013, pp 1-10
3. Fiaz Majeed, Aslam Muhammad, Rizwan Saleem and Martinez-Enriquez A."Towards Maturity in Multi-agent Based Remote Patient Monitoring", *International journal of multidisciplinary sciences and engineering*, vol. 2, no. 1, march 2011
4. D. Isern, D. Sanchez, A. Moreno, "Agents applied in health care: A review", *International Journal of Medical Informatics*, 79(3): 145-166, 2010.
5. Della Mea, Vincenzo, "agents acting and moving in healthcare scenario - A paradigm for telemedical collaboration", *IEEE Transactions on IT in Biomedicine*, pp.10-13, 2001.
6. R. Sulaiman, X. Huang, D. Sharma, "E-health services with secure mobile agent", *In proceedings of the international conference on communication networks and services research*, 2009.
7. J. Y. Khan, M. R. Yuce, F. Karami, "Performance evaluation of a wireless body area sensor network for remote patient monitoring", *In the IEEE 30th annual International Conference on Engineering in Medicine and Biology Society (EBMS)*, 2008.
8. M. Pinsker et al. "Experiences using Mobile Phones as Patient-terminal for Tele-medical Home Care and Therapy Monitoring of Patients Suffering form Chronic Diseases", *Computers Helping People With Special Needs, Springer Lecture Notes in Computer Science*, 2008.
9. J. O'Donoghue, J. Herbert, P. Stack, "Remote non-Intrusive Patient Monitoring", *In the 4th International Conference on Smart Homes and Health Telematic (ICOST)*, 2006.
10. A. Aguilera, A. Subero, "A multi-agent architecture and system for dynamic medical knowledge acquisition", *In proceedings of the international conference on computational intelligence for modeling, control and automation; intelligent agents, web technologies and internet commerce; and innovation in software engineering*, pp. 1165-1170, 2008.
11. Alexander G. Logan, Warren J. Mcisaac, Andras Tisler, M. Jane Irvine, Allison Saunders, Andrea Dunai, Carlos a. Rizo, Denice s. Feig, Melinda Hamill, Mathieu Trudel, and Joseph A. Cafazzo. "Mobile Phone-Based Remote Patient Monitoring System for Management of Hypertension in Diabetic Patients", *AJH* 2007; 20:942-948
12. Abhiman Hande, Todd Polk, William Walker and Dinesh Bhatia, "Self-powered Wireless Sensor Networks for Remote Patient Monitoring in Hospitals", *Journal on the Science and Technology of Sensors and Biosensors*, September 2006
13. Babcock, "Models and issues in data stream systems," *In proceedings of the 2002 ACM Symp. on Principles of Database Systems*, June 2002.



14. Widomet., “*Query Processing, approximation, and resource management in a data stream management system,*”, *proc. of the CIDR Conference, 2003.*
15. F. Majeed, M. S. Mahmood, “*Efficient Data Streams Handling in the Real-Time Data Warehouse*”, *IEEE ICICT, Chengu, China, 2010.*
16. Asa G., Daniel L., David A., “*A Pattern Supported Approach to the User Interface Design Process*”, *Int. conf. on HCI, New Orleans, USA, 2001.*
17. M. Taleb, A. Seffah, A. Abran, “*Patterns-Oriented Design Applied to Cross-Platform Web-based Interactive Systems*” *IEEE Int. Conf. IRI, pp.122 – 127, 2007.*