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Multi-Agent Based Software Architecture for Remote Health Monitoring

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Abstract

Objectives: Multi agent Architecture is a recent advancement in software engineering that focuses on improving performance of software packages and tools in varying applications. **Methods/Statistical Analysis:** Large number of architectures have been proposed for remote health monitoring applications which include data collection from remote patients and monitoring the condition. There is little work done on software systems monitoring multiple patients with multi-parametric approach from remote locations efficiently and faster. This paper presents a multi-agent architecture to monitor concurrently multiple physiological parameters of multiple patients situated at remote places. The architecture proposes three types of software agents such as patient controller interface agent, controller agent and server agent. Real time system can be scaled up to any number of patients being monitored for any variable number of physiological parameters. It is time critical application as the patients being monitored need immediately attention or treatment. **Findings:** For validating the proposed architecture the data has been collected for Temperature, blood pressure of patients and software agents designed were implemented and tested under multiple combinations of number of parameters and the patients. The test results proved that the proposed architecture is useful for efficient and quick monitoring of severely diseased people from remote places. **Application/Improvements** Tele-monitoring is widely used in a range of applications such as natural calamities like disaster, floods etc.

Keywords: Arduino, Multi Agent Architecture, Remote Health Monitoring, Software Engineering, Telemedicine

1. Introduction

Design and deployment of remote health monitoring system is the need of the era as there is enormous increase number of patients with rising population.[11] On the contrary there is not substantial increase in number of expert medical doctors. Prior research works has focused on either architectural approach of total remote health monitoring with centralized control or study of individual patients physiological parameters related to health. Telemedicine (TM) is a tool for more efficient exploitation of available resources involved in improved patient–physician relationship.[7,8] This method has been implemented in many organizations but still lacking with capability to handle the situation efficiently. Starting from the Computer based Patient Record (CPR) which was often a longitudinal record that captured paper based information in an image format for later reference to the Electronic Medical Record (EMR) which encompasses the CPR and more, EMR was unable to provide medical services to rural areas since its capability was limited only to a particular organization or an enterprise.

It has now become essential to redefine TM in such a way so as to improve Doctor to Patient Ratio. While many visionaries believe that increasing doctors is the only solution to handle this problem, investigations &

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surveys in many health modalities have revealed that early detection of any abnormality can reduce the risk of health and thereby reduce the number of critical diseased patients and the number of expert medical doctors. The literature states that the perfect solution for this problem will originate only when an application is designed using telemedicine concept involving large set of remotely located patients being monitored by a smaller set of medical experts. It needs a solution that is able to collect securely patient's data from various locations across city, across state and across country, process and makes available to medical experts of interest. The assets of an Electronic Health Records (EHR) with improved capability can facilitate the exchange of health information with lowering healthcare costs. The information such as performance, laboratory evaluation, diagnostic design records, prescriptions, medicines, narcotic administered, patient recognition information, legal permissions, and allergies are contained in EHR. Initially this information was stored in various proprietary formats through a multitude of medical information systems available in the market. Typical formats include relational database table's structured document-based storage in various formats and unstructured document storage such as digitized hardcopies maintained in a classical document management system. Creating structured database and transporting patients report accordingly between care sites can speedup treatment and reduce multiple testing and diagnosis. Automatic indications may reduce errors, increase production, and help in patient care. Moreover one of the innovative ways in the remote health monitoring is to use blind approach in remote areas where patients and doctors interaction is not compulsory.[1]

In the evolution of Telemedicine architectures, a variety of experiments have been performed using different architectures. One of the earliest researches in Telemedicine is a Rubee based Architecture in which Rubee technology has been used.[2] It provides a dynamic, programmable and wireless network with which communication in remote areas could be possible. The architecture provided security and better transmission distance. It was proposed a service oriented architecture that used Open Services Gateway initiative (OSGi) to present a home centered remote health monitoring system with a blind approach.[3] Recently an Agent based approach was proposed which also used service oriented architecture to optimize the quality of medical data.[4] An evolutionary algorithm has been used in this architecture. Many of the researchers validated their proposition through examination of certain physiological parameters. As presented the work to examine physiological parameters.[5] Body parameters like Temperature and Heart Beats were measured by a data acquisition system. LPC 2148 ARM controller, Bluetooth and GSM module were used for validation of the proposed work. Multi Agent concept is a new innovation in the field of remote health monitoring.[9] The Multi Agent approach consists of many agents throughout the network which interact with each other by transferring messages either by wired or wireless connection. Telemedicine needs research on architectures and physiological parametric requirements and their context of utilization. There is major research focusing physiological parameters and their analysis for disease diagnosis. The Service oriented Architecture removes the problem of semantic interoperability, provides features like reliability, portability and flexibility.[10] However SOA is not well suited for heterogeneous interoperability and also not focused on physiological parameter. The Multi Agent based Architecture deals with problems like scalability i.e. increases load sharing capability in distributed architecture. Decentralization avoids single point of failure as all the agents have the capacity to forward data. This paper presents a multi-agent based architecture to create a large scale remote health monitoring system. The concept presented can be useful in creating a real time remote health monitoring system with health data repository, access and serviceability.

2. Classification of Telemedicine Services

The Telemedicine services are broadly categorized into two major issues:-

1. Architectural Proposition
2. Independent physiological parameter studies

Various research papers, reports and articles were studied through typical review procedure to read and analysis the details. The research papers were categorized on the basis of architecture and various physiological parameters of human body.

3. Proposed Architecture of Health Monitoring

The proposed architecture consists of three agents such as controller-patient interface agent also called as router agent, Controller agent and Server agent. Assuming that the device used for recording physiologi-

cal parameter at patients' end is capable of processing the recorded parameter, packaging the parameter information and sending it to the router connected. The purpose of the router agent is to collect the patient's physiological parameters, such as ECG, blood pressure, temperature etc. either in singular mode or in multiple. After collecting these packets, the Router Agent needs to insert its own IP address as identification of the patient and forward them to the Controller Agent. There can be as many router agents as that of number of patients. The router agent need to maintain table of information related to patient's parameters. If any new parameter is received, the information is updated in table. The controller agent receives packets from router agents, processes them and forwards to the server agent. In addition, the controller agent checks patient and the parametric information from its table. Any new entry is updated. Figure 1 shows the architectural diagram of the proposed remote health monitoring system.

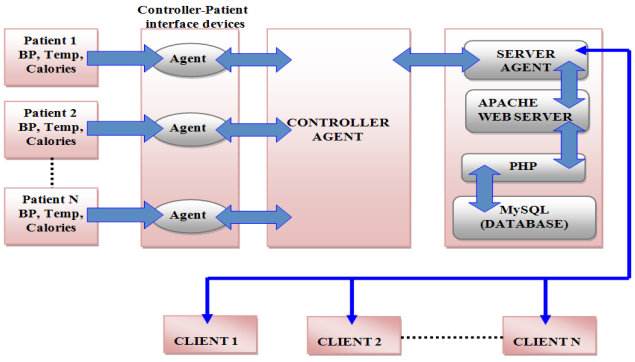

Figure 1. Proposed Architecture of Tele-Medicine remote monitoring of multi patients.

The third component of the system is Server storing all the data in the database coming from the Controller Agent. The server has to maintain patient wise records of various physiological parameters such as ECG, blood pressure, temperature and other physiological parameters in the database table along with the patient name, patient ID and parameter ID. The server agent need to extract patient id and the parameter received from the packet and match with the available database, if it exist update/store new data and add the details to the database if not found. The client is a doctor who can access/observe patient information. These clients may also be patients themselves or their relatives. All requests from various clients are handled by the Server Agent. So Server-Agent acts as the interface between the client and the database and controller agent and the database. Whenever a client sends a request, the Server-Agent searches for requested patient and the parameter in the database and generates report for the Client. The generated report is sent to the client.

4. Validation of Proposed Architecture for Remote Health Monitoring

In order to validate the proposed concept a simple architecture with two patients and two physiological parameters each has been considered for implementation. All the three types of agents are designed and implemented as per architecture shown in Figure 2. The patient's data has been taken in standard form from SD card and stored on Arduino Kit for processing. In this implementation we have not collected data in real time but from offline database has been considered. Two Arduino kits are used for two different patients.[6] The patient-controller interface agent reads Physiological parameters BP and temperature stored in SD card of the kit and transmits wirelessly.

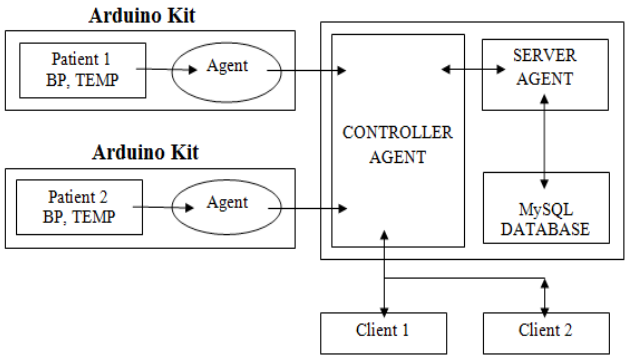

Figure 2. Validation Architecture of Remote Health Monitoring.

Every kit has been assigned by an IP address as a Patient ID. Controller agent and server agents along with database have been deployed in the same machine. Upon receiving the data, controller agent extracts IP address (Patient ID) and the name of the parameters. Further it checks through server agent in the database if concerned patient does exist, appends data in the database of specific physiological parameters otherwise adds an entry of patient/ parameter in the database table and records it. The server agent has to play dual role one as interface between controller agent and database and other between client and database. Whenever

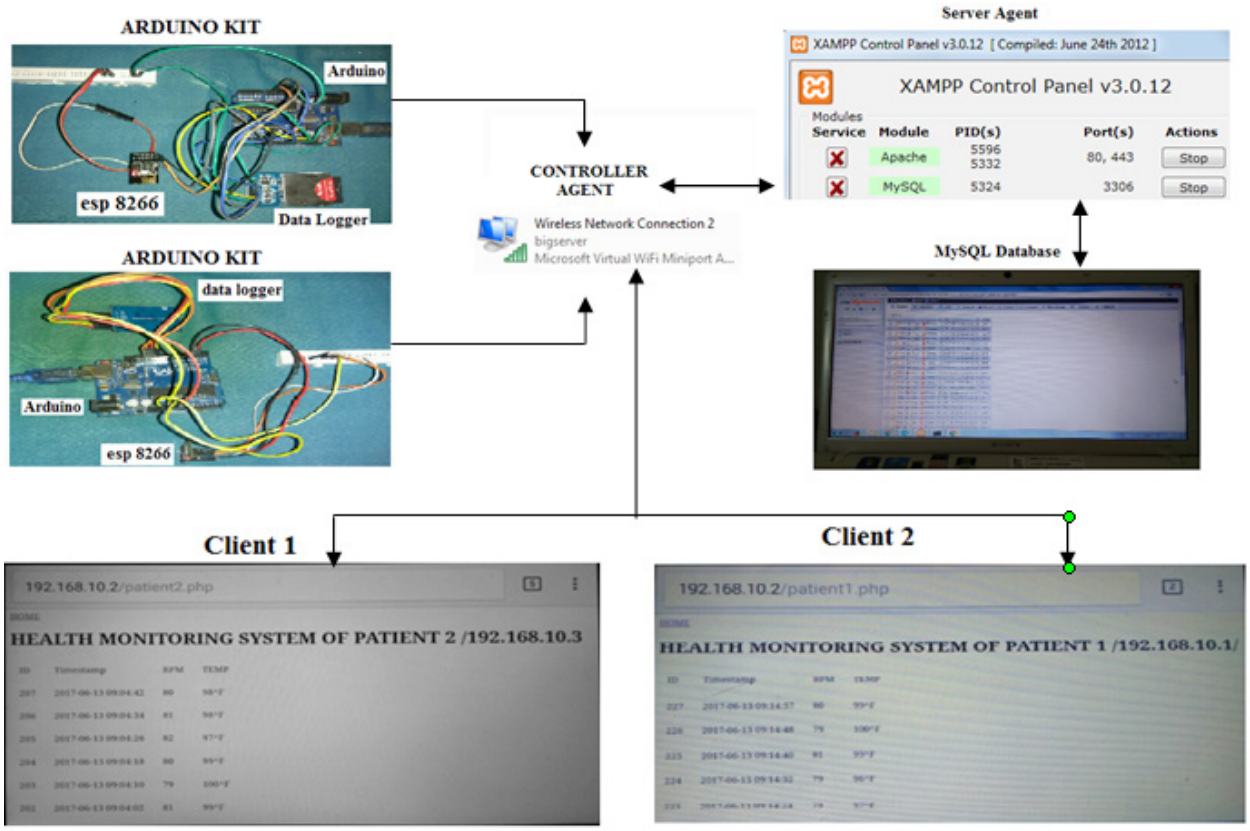

Figure 3. Pictorial View of Tested Architecture.

the client logs in and sends a request for patient data whether live or stored data, the server agent checks database for stored or live incoming data and send it back to the client. Figure 3 shows pictorial view of the implementation showing connectivity of various components.

In the implemented architecture Arduino kit (esp 8266, data logger with SD card, Arduino UNO) has been used as patient and the interface agent. In the Arduino kit esp 8266 is used as a Wi-Fi module which is used to transmit BP and temperature of patient which is stored in the SD card along with data-logger. In the implemented architecture, the Apache web server has been used to create Server-Agent. Server-Agent stores data in mySQL database created through PHP programming language. Client in the architecture can retrieve data from the Controller-Agent and generate reports.

5. Result and Discussion

In order to observe the physiological parameters of patients by Clients (Doctors) a homepage has been created which can be opened using the link: ***192.168.10.2/data.html***, where 192.168.10.2 is the IP address of Server Agent "bigserver". The bigserver displays links to the data of registered patients to the doctor. Figure 4 shows that there are two patients, patient 1 and patient 2. The IP address of the patient 1 is 192.168.10.1 and the IP address of the patient 2 is 192.168.10.3 and there are six links shown as:

1. link 1.1 is used to see the Blood Pressure and Temperature of the Patient 1.
2. link 1.2 is used to see only the Temperature of the Patient 1.
3. link 1.3 is used to see only the Blood Pressure of the Patient 1.
4. link 2.1 is used to see the Blood Pressure and Temperature of the Patient 2.
5. link 2.2 is used to see only the Temperature of the Patient 1.
6. link 2.3 is used to see only the Blood Pressure of the Patient 1.

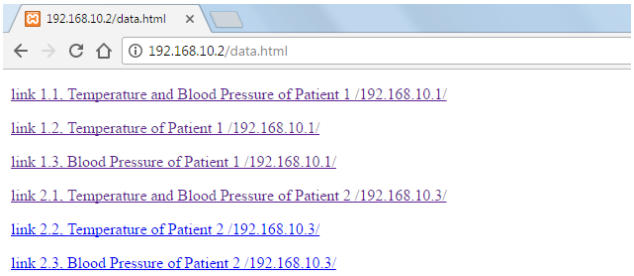

Figure 4. Client GUI Interface.

In order to test the architecture working when multiple patients communicating multiple physiological parametric data in real time, following four different scenarios were considered:

Scenario I: One patient with one physiological parameter
Scenario II: One patient with two physiological parameters
Scenario III: Two patients with one physiological parameter
Scenario IV: Two patients with two physiological parameters

5.1 Scenario I: One Patient with One Physiological Parameter

This is the case when client want to access only one physiological parameter like temperature, they have to click on the link 1.2 or link 2.2 of patient 1 or patient 2 respectively.

Figure 5 shows the temperature of patient 1 whose IP address is 192.168.10.1.

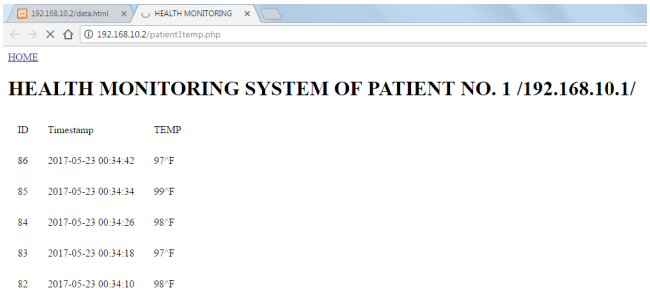

Figure 5. Scenario I browsing from Client side.

5.2 Scenario II: One Patient with Two Physiological Parameters

This is the case when client want to access two physiological parameters like temperature and blood pressure, need to click on the link 1.2 or link 1.3 of patient 1 or patient 2 respectively.

Figure 6 shows the blood pressure and temperature of the patient 1being recorded simultaneously in real time from IP address is 192.168.10.1.

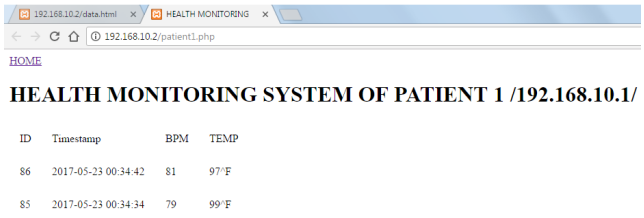

Figure 6. Scenario II browsing from Client Side.

5.3 Scenario III: Two Patients with One Physiological Parameter

This is the case when the client wants to excess single physiological parameters like temperature or blood pressure of two different patients simultaneously, need to click on the link 1.3 and link 2.3 of patient 1 and patient 2 respectively. Figure 7 shows one parameter of two patients simultaneously.

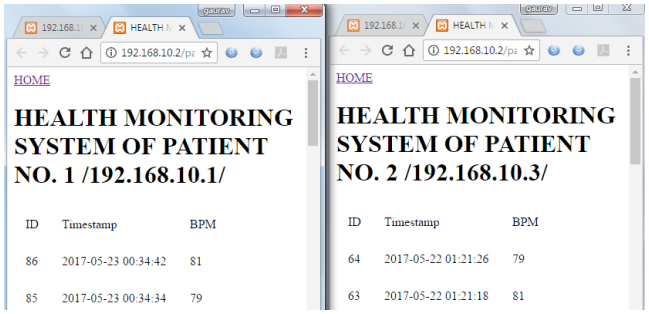

Figure 7. Scenario III browsing from Client Side.

5.4 Scenario IV: Two Patients with Two Physiological Parameters

This is the case when the client wants to excess two physiological parameters temperature and blood pressure simultaneously for two patients, need to click on the link 1.1 and link 2.1 of patient 1 and patient 2 respectively. Figure 8 shows two parameters of two patients simultaneously.

For the validation of proposed architecture a database is created and stored with the help of Apache Web Server, which provide the medium to the Clients to see and check the health parameters of the patient. At the same time the data is stored on the mySQL database and will remain in the database until it is deleted from the database. The Figure 9 shows mySQL database on web server.

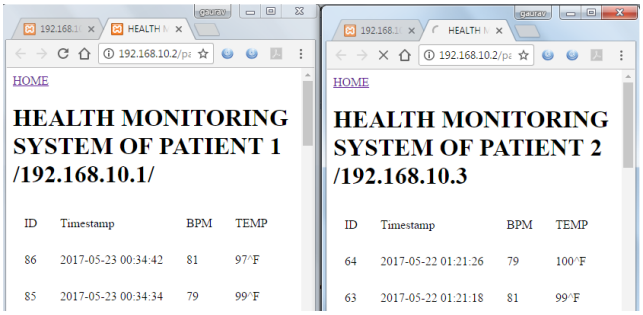

Figure 8. Scenario IV browsing from Client Side.

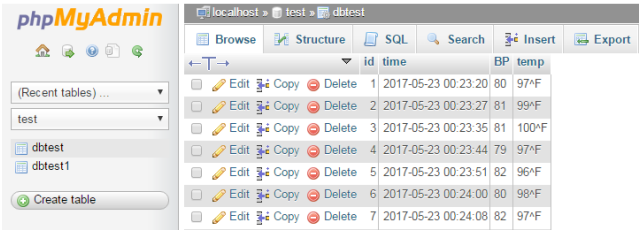

Figure 9. Data store in mySQL database for Patient 1.

This shows that the concept can be extended for any number of patients with any desired number of physiological parameters recording and diagnosis.

6. Conclusion

In this study we have presented a multi-agent based architecture for remote health monitoring of critically ill patients. The proposed architecture has been validated through its implementation for two patients with two physiological parameters each considering four different scenarios. The main feature of the architecture is that it is capable and effective for large number patients located at remote place to be monitored by limited number of expert doctors geographically located at far off places. This work does not take into consideration the security and privacy of data while transmitted, stored and analyzed. It can be extended in future to incorporate the security. The validation results prove that it can be extended to any number of patients irrespective of their locations and also any number of their physiological parameters to be monitored.

7. References

1. Avritzer A, Bondi A, Grottke M, Trivedi KS, Weyuker EJ. Performance assurance via software rejuvenation: monitoring statistics and algorithms. Proc International Conference on Dependable Systems & Networks (DSN); 2006. p. 435–44. Crossref
2. Xiaohua Y, Xiangling X, Xuhui Chen. ICIS '11 Proceedings of the 2011 10th IEEE/ACIS International Conference on Computer and Information Science; 2011 May 16-18. p. 365–70.
3. Spinsante S, Ennio G. Remote health monitoring by OSGi technology and digital TV integration. IEEE Transactions on Consumer Electronics; 2012; 58(4).
4. Wu CS, Ibrahim K, Hemant S. Optimizing medical data quality based on multiagent web service framework. IEEE transactions on information technology in biomedicine. 2012; 16(4):745–57. Crossref PMid:22614723
5. Girhepunje VG, Santosh DC. Realization of low power telemedicine system to monitor temperature and heart beats. IEEE International Conference on Energy Systems and Applications; 2015.
6. Gibb AM. New media art design and the Arduino microcontroller: A malleable tool. [PhD thesis]. Pratt Institute; 2010.
7. Zhou Z. The Design and Implementation of a Portable EIT Telemedicine System. Second International Conference on IEEE on Intelligent System Design and Engineering Application (ISDEA); 2012. Crossref
8. Kannoju PK, Sridhar KV, Prasad KSR. Design and Implementation of a Novel approach to implement Telemedicine in Rural India using advancements made in Communications and Information Technology. Intelligent Systems Modelling and Simulation (ISMS) Second International Conference on IEEE; 2011.
9. Lather D, Suman A. An Agent Based Architecture for Telemedicine System-A Conceptual Approach. Advances in Recent Technologies in Communication and Computing ARTCom'09. International Conference on IEEE; 2009. Crossref
10. Polze A. A scalable, self-adaptive architecture for remote patient monitoring. 13th IEEE International Symposium on Object/Component/Service-Oriented Real-Time Distributed Computing Workshops (ISORCW); 2010. Crossref
11. Rotariu C. Remote monitoring of body caloric expenditure using wireless devices. 9th International Symposium on Advanced Topics in Electrical Engineering (ATEE) IEEE; 2015. Crossref