Available Online at www.ijcsmc.com

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X

IJCSMC, Vol. 2, Issue. 12, December 2013, pg.88 – 94

RESEARCH ARTICLE

Remote Patient Tracking and Monitoring System

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Abstract— The increasing number of patients needing continuous care is an encumbrance for medical staff. Today patient monitoring system along with wireless medical devices is used to monitor the patients, but still the patients have to stay inside coverage area of wireless devices. In this paper a remote patient tracking and monitoring (RPTM) system is proposed. The system monitors patient's vital signs via wireless medical sensors. The medical sensor sends the data to an Android based mobile device, which, in turn, periodically sends the patient health data to the server. The proposed system allows the patients to change their position freely; it tracks them using the collected GPS data from the mobile device and directs them to medical care team at any health emergency case. Also, the server informs the patient's doctor about his patient's status and position. A dedicated simple compression method is used to reduce the GPS data size, which is periodically collected. The proposed system components communicate with each other through a third party and there is no direct access between them. The transmitted data is encrypted by P2P key using AES. The doctors can do query about their patients using a dedicated Android based application. Also, they can query using an established web server.

Keywords— patient monitoring; Android; GPS

I. INTRODUCTION

The health field has been one of the most important study fields as it is related directly to the human's life. Previously, healthcare was focused on institutional care and on curing diseases, which is diagnosis-based treatment only. Patients only approach medical professionals when they are not feeling well [1]. For some patients it is necessary to control their health status periodically. This need for measuring patient's vital signs enforces him to stay in the hospital, at the same time it is required for medical staff to take care of this measuring process.

The increasing cost of healthcare services has created several challenges on how to provide better healthcare services to an increasing number of people using limited financial and human resources [2]. The mobile healthcare applications have become more favourable nowadays due to the emphasis on healthcare awareness and also the growth of mobile wireless technologies [1]. The Android technology is used in some researches [1], [3]-[6] to develop patient monitoring system. Some of the published studies have been expected that the users of mobile healthcare applications will be over 100 million at 2015, which indicates the importance of mobile health monitoring applications [7].

There are many published researches to help in controlling the patient status in wireless area; the wireless medical device receives information from sensors that put on the patient body wirelessly, this information also can be read wirelessly by medical staff. These systems do not require the patient to be limited to his bed and allow him to move around but requires being within a specific distance from the bedside monitor. Out of this range, it is not possible to collect data [8].

Some researchers have investigated the use of GSM [9]-[11] to send health information to medical care sites. This gives patient the ability to leave the hospital but still he has to stay in some known places to ensure the ability to reach him in emergency cases. Even with this solution the patient can't move freely and be far from his home; therefore, a critical need is arises to extend such idea to wider area and to cover more people and give them more live mobility, just like in their normal life. These new systems should be capable to check their health information remotely and automatically detect the abnormal health cases and, also, allocate their positions for emergency purpose.

In this paper the suggested system checks patient health status using wireless medical device that is connected to an Android based mobile device, also track patient's position using internal GPS sensor. This mobile device reads health information (i.e. temperature, heart rate and blood pressure) from the wireless medical devices, and in addition stores them locally before sending them to server via GPRS; it also checks for abnormal health status, and in case of occurrence of such abnormal status the mobile devices generates an alarm and sends emerging alarm to the server. The server does a set of emergency steps to direct patient to a medical care team and, if needed, ensures that a medical care team will reach the patient. All local and remote information are encrypted to ensure secrecy of sensitive data (such as position of each patient).

II. SYSTEM SPECIFICATIONS

The proposed system is designed to introduce a healthcare infrastructure that supports human health safety depending on new emerging technologies. The structure of proposed system consists of six main parts. Each of them has specific functions as following:

1. *Medical Sensation*: the vital signs of the patient are periodically caught wirelessly by the medical sensors attached on patient body.
2. *Medical Processing and Analysis:* The vital signs of the patient are analysed and checked depending on the medicine standards to detect abnormal health status of the monitored patient.
3. *Alarm Assurance*: in case of abnormal health status a set of emergency steps (including sending alarm message via GPRS connection, calling emergency centre to open live voice channel and generating alarm sound) is executed.
4. *Position Allocation:* patient's position is monitored continuously to ensure the ability of reaching the patient in emergency situation.
5. *Communication Media:* although GPRS is used as primary communication media, the services of sending Email and establishing voice channel are used as alternative methods in emergency cases.
6. *Medical Archiving:* patient's health information is stored locally on patient local database as well as on main DB.

The system can simultaneously covers different stages of operations, the main stages are:

1. *Registration and Information Updating:* in this phase, the system handles the patient's registration process. The registration task includes fixing the patient and doctor information. These information elements can be partially updated at any time as long as the system works.
2. *Monitoring:* the system, in this mode, monitors patients' health status and their position.
3. *Emergency Handling:* at any emergency instance (i.e., when the health of a patient is not normal), the system performs a set of operations to make sure that the patient will be safe and, if needed, a medical care team can reach him as soon as possible.

There are three main types of players in the RPTM system; each of them has its own responsibilities, and plays a specific role in the system.

1. *Patient:* it is the main player in the system whose health status is the main concern which should be covered by the system. Patient should be supplied with Android mobile device that follows the patient location (using the embedded GPS receiver) and the vital signs (received from the medical sensors), figure (1) shows the dedicated application which contains patient's health and position information. The mobile device processes the collected health data, stores them locally and sends them periodically to the server.

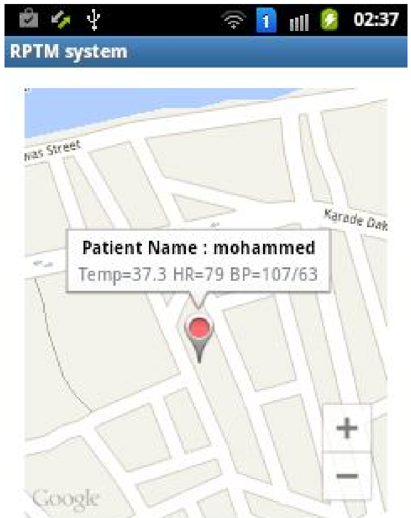

Fig.1 Patient's information

2. *Doctor:* uses Android mobile device to conduct queries about the current patient's vital signs. The doctor record ID should be registered in the system. In case of patient's emergency status, the doctor will be informed via alarm messages originated by the server. Also, he can query about his patient(s) health status using the web service.
3. *System Administrator:* the system works as an automated as possible; although the system administrator in some cases is needed to change the workflow or take a decision when there is need for human interaction.

All data frames that are transferred between the system components are encrypted using AES. Each system component has a dedicated P2P AES key with the server. This encryption provides both message confidentiality and authentication. Figure (2) illustrates the applied system message encryption scheme. The doctors can communicate with the patient for checking his health status exclusively via the server. There is no direct message transfer between components. This allows high level of security; if the privacy of one of the devices in the system has been breached, it only affects the link between that device and the server; other components which have different AES keys and no direct link with the breached device are completely in safe.

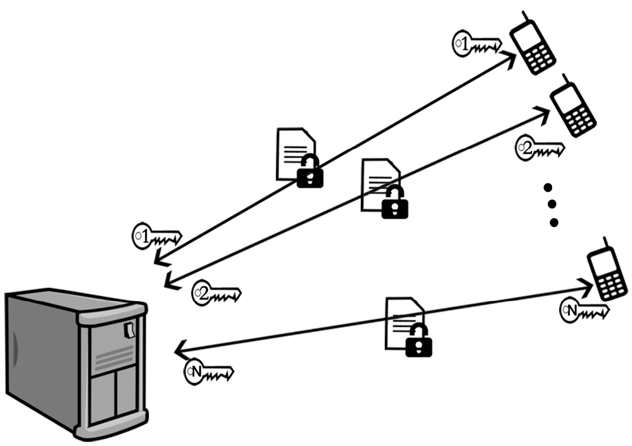

Fig.2 Message encryption scheme

The RPTM system is related to the patient's life. The designed system should satisfy a number of requirements, as in the following:

1. Beside to keeping the current patient's health data, the system should, also, keep the historical data of patient, at least to certain time period extent.
2. The system should allow doctors to ask about the current and/or historical health status of their patients. Also, at the emergency cases they should be informed about their patients periodically.

3. The system deals with sensitive personal data, so it has to keep them secure (i.e. confidentiality, preservation).
4. The data inside the system are important because they related to patients life. These data should reach their destination, with high degree of confidence; that is, there is no possibility for the occurrence of data loss in the system.
5. The system has to give patients the capability of moving free and not enforce them to stay is specific place (i.e., the system should track the patient's position).
6. In case of security breach occurrence on one of the patient's device, its effect should be kept local and not propagated to other system components and put them in danger.
7. The system is heterogeneous in terms of its components. So, they have to be synchronized and communicate with each other in smooth and independent way.

III. SYSTEM WORKFLOW

Two types of paths the system can flow. The first one works with the ordinary case; in such case the system just collects the patient's data periodically. The second path is followed when emergency case is occurred.

Figure (3) illustrates the system routine functional flow of the proposed RPTM system. The patient's mobile device is connected to the medical device wirelessly which gives the patient mobility within the coverage area, while the medical sensor is connected to patient's body to read his health data, then the data are send to the patient's Android based device. The patient's mobile device receives patient's health data (temperature, heart rate and blood pressure) periodically. Also, it receives the GPS signals, using internal GPS receiver, in order to register patient's location data. When the patient changes his location the position data is updated. The collected health data in addition to encrypted location data is stored in the local database of the Android mobile device itself; also, it processes the health data as long as they are received from the medical sensor.

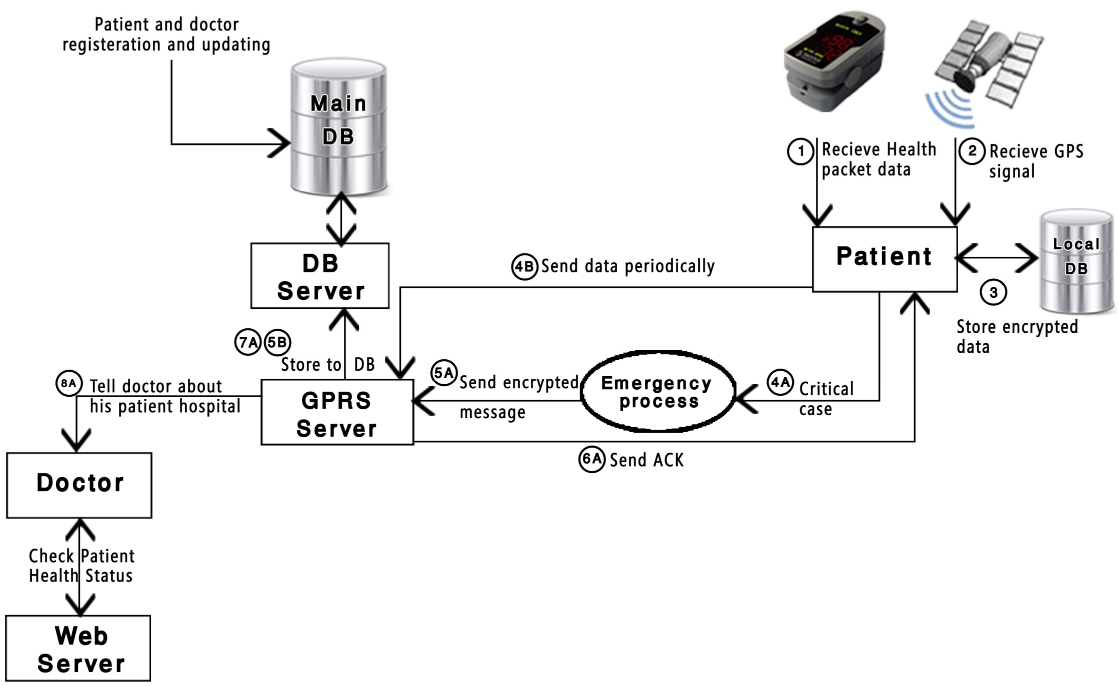

Fig.3 The proposed system work flow

If the patient health is normal, then the patient's device encodes and encrypts these vital signs together with location data, and sends them to the server every specific period of time as encapsulated tag of data. At the other side, when the GPRS server receives the sent tag from patient device, first the message will be decrypted then the packets will be decoded and applied.

If the patient health is abnormal then the system will conduct a set of emergency tasks beside to sending the patient's data to the server. After receiving the emergency packet (sent from the patient module) the server issues rescue alarm to an available medical care team for help.

When patient is in an emergency case the system tracks his position continually till reaching the medical care team to him. Since the latitude and longitude coordinates values, in the captured GPS data frames are represented using double precision format, so the system needs 128 bits for registering each location data (i.e., latitude/longitude values). Even if the GPS system uses 64 bits instead of 128 bits format, this amount is too large and does not fit the patient location precision requirements. A simple and fast GPS data compression method [12] is used to ensure that the GPS data takes as minimum as possible and guarantee the location accuracy.

The doctor can query about his latest patient health status using a dedicated application. If the doctor want the historical information about his patient he can access the web server, use his password for authentication, then he will be able to do the required queries about his patient's historical health data. The web server is established using Apache web server. PHP is used as server-side HTML embedded scripting. The web server query process is illustrated in figure (4); it is consist of the following steps:

1. The doctor should authenticate himself. This is done by a dedicated password fed through a HTML page. The embedded PHP script will check the input data.
2. After authenticating the doctor, he will be granted the required authorization to conduct the required query about the patient's information. For security reason, the doctors can not query about the patient's position, through the web server only the patient's health status could bet browsed.
3. The doctor should enter the patient name and the required specific vital sign. Then a PHP page is connected with the main DB in order to retrieve the patient information. To do so the "php_com_dotnet.dll" library is used.

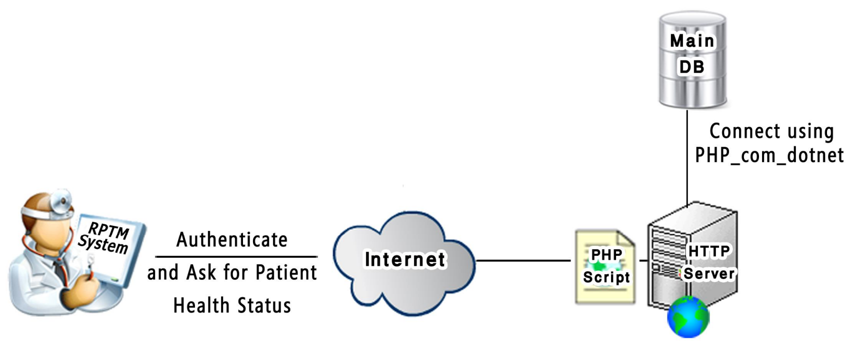

Fig.4 HTTP server querying diagram

IV. Patient Module Test

The patient's device is a mobile device supported with Android operating system, it uses sqlite database which is a light version of SQL. The patient's device stores the latest patient's location, his historical vital signs and the time of data record. The frequency of data registration is variable because it depends on the type of vital sign and its relevancy to his disease.

Each vital sign's type has specific normal and abnormal ranges. In the following the dynamic range of some vital signs for adults are given [13]:

1. The normal values of temperature are between 36^{o}C and 38^{o}C. When the temperature reaches 40^{o}C it indicates the panic level.
2. The normal values of heart rate are between 60 and 100 beats/min. While, the heart beats rate less than 45 beats/min or greater than 130 beats/min indicate panic level.
3. The normal values of diastolic blood pressure are between 60 and 90 mmHg. The panic levels are less than 55 mmHg and greater than 120 mmHg.
4. The normal values of systolic blood pressure are between 90 and 130 mmHg. The panic levels are less than 80 mmHg and greater than 200 mmHg.

The vital sign's value is represented using 8 bits. To represent temperature with (0.1^{o}C) resolution, a simple indexing system is used. For linear indexing system with 8-bits index size, a set of 256 index values can be registered. The index value (V_{idx}) for each temperature value (V) is computed using the following equation:

$$V_{idx} = round\left(\frac{V - Min}{R}\right) \qquad \text{……} (1)$$

Where, *Min* in the minimum possible value, by dividing the 256 indexes the *Min* value is considered to be 24.2. *R* is the numeric resolution. The approximation value (V') is retrieved from (V_{idx}) using the following:

$$V' = V_{idx}R + Min \qquad \text{…… (2)}$$

In addition to the sample value, each record has a flag (which is 2 bits length) indicates the sample type (i.e., normal or abnormal with different levels). Also, the date and time of registered sample requires 48 bits. For speeding up the data access, the minimum used unit for each value is taken byte (instead of bit). The sampling rate of each vital sign for each patient is variable because it depends on the patient health problem case. For each health problem case the vital signs have to be check at different sampling rates. Table (1) shows the various data storing types, sampling rate and their required storage spaces in a specific period of time.

TABLE I
SAMPLE SET STORAGE SPACE

Sample Type(s)	Sample Rate (sample/day)	Size/Day	Size/Week	Size/Month	Size/Year
Temperature/ Heart Rate	1	8B	56B	240B	2.81K
	2	16B	126B	540B	6.33K
	3	24B	168B	720B	8.44K
	4	32B	224B	960B	11.25K
	8	64B	448B	1.88K	22.5K
	12	96B	672B	2.81K	33.75K
	24	192B	1.31K	5.63K	67.5K
Temperature and Heart Rate	1	16B	112B	480B	5.63K
	2	32B	224B	960B	11.25K
	3	48B	336B	1.41K	16.88K
	4	64B	448B	1.88K	22.5K
	8	128B	896B	3.75K	45K
	12	192B	1.31K	5.63K	67.5K
	24	384B	2.63K	11.25K	135K
Blood Pressure	1	9B	63B	270B	3.16K
	2	18B	126B	540B	6.39K
	3	27B	189B	810B	9.49K
	4	36B	252B	1.05K	12.66K
	8	72B	504B	2.11K	25.31K
	12	106B	742B	3.11K	37.27
	24	216B	1.48K	6.39K	75.94K
(Temperature/ Heart Rate) and Blood Pressure	1	17B	119B	510B	5.98K
	2	34B	238B	1K	12K
	3	51B	357B	1.49K	17.93K
	4	68B	476B	1.99K	23.91K
	8	136B	952B	3.98K	47.81K
	12	204B	1.39K	5.98K	71.72K
	24	408B	2.79K	11.95K	143.44K
Temperature , Heart Rate and Blood Pressure	1	25B	175B	750B	8.79K
	2	50B	350B	1.46K	17.58K
	3	75B	525B	2.2K	26.37K
	4	100B	700B	2.93K	35.16K
	8	200B	1.37K	5.86K	70.31
	12	300B	2.05K	8.79K	105.47K
	24	600B	4.1K	17.58K	210.94K

V. CONCLUSIONS

The system operation is stable, accurate in monitoring and detecting patient's emergency case. Also, it is proactive by responding quickly to the patient has critical health status. A set of tests is conducted on the patient's application; the results indicate that in case of using slow and single core processor, the application takes 0.9% of the processor time, so the patient's application can work beside other running applications without causing significant degradation in the performance of the device.

The health data of a patient can be saved in the local database as needed. This means that even if the patient needs to check his vital signs every hour and one year historical health data has to be locally available in his mobile device; this needs less than 0.3 MB, which is low storage size requirement relative to the available storage supported by the modern mobile devices.

For future work the following is suggested:

1. Use backup connection to GPRS in case of inaccessibility to GPRS connection.
2. Use automated smart medical care team finder to find the nearest medical care team.
3. Using Secure Sockets Layer/Transport Layer Security (SSL/TLS) with certificates in HTTP server to ensure more security immunity level.
4. Raising the communication services between patients and their doctors; for example adding the services of sending pictures and videos.
5. Use indoor positioning techniques (for example, via built-in sensors in an Android device; such as gyroscope and accelerometer) to be able to track the patients inside buildings.

REFERENCES

[1] P. Hii, W. Chung, *A Comprehensive Ubiquitous Healthcare Solution on an Android Mobile Device,* Sensors (14248220), Vol. 11, Issue 7, pp.6799-6815, 2011.

[2] U. Varshney, *Patient monitoring using infrastructure-oriented wireless LANs*, Int. J. Electronic Healthcare, Vol. 2, No. 2, pp.149-163, 2006.

[3] B. Holl, *Design and Development of a Mobile Computerized Glucose Management System to Support Inpatient Care for Patients with Diabetes*, Master's thesis, Graz University of Technology, Austria, 2011.

[4] G. Koshmak, *An Android Based Monitoring and Alarm System for Patients with Chronic Obtrusive Disease*, M.Sc. thesis, Örebro University, Sweden, 2011.

[5] M. A. Matin, R. Rahman, *Android-Based Telemedicine System for Patient-Monitoring*, North South University, Bangladesh, 2012.

[6] P. Sundaram, *Patient Monitoring System Using Android Technology*, International Journal of Computer Science and Mobile Computing, Vol. 2, Issue 5, pp.191-201, May, 2013.

[7] V. Pournaghshband, M. Sarrafzadeh, P. Reiher, *Securing Legacy Mobile Medical Devices,* Wireless Mobile Communication and Healthcare - Third International Conference, MobiHealth, pp. 163-172, Paris, France, November 21-23, 2012.

[8] M. Aminian, H. R. Naji, *A Hospital Healthcare Monitoring System Using Wireless Sensor Networks*, J Health Med Inform 4: 121. doi:10.4172/2157-7420.1000121, 2013.

[9] S. Khoor, K. Nieberl, K. Fugedi, E. Kail, *Telemedicine ECG-telemetry with Bluetooth technology,* Proceedings of the Computers in Cardiology, Rotterdam, pp. 585-588, 2001.

[10] N. P. Jain, P. N. Jain, T. P. Agarkar, *An embedded, GSM based, multiparameter, realtime patient monitoring system and control—An implementation for ICU patients,* Information and Communication Technologies (WICT), IEEE, pp. 987-992, 2012.

[11] J. S. Adivarekar, A. D. Chordia, H. H. Baviskar, P. V. Aher, S. Gupta, *Patient Monitoring System Using GSM Technology*, International Journal Of Mathematics And Computer Research, Vol. 1, issue 2, pp. 73-78, 2013.

[12] M. B. Albujeer, L. E. George, *Simple Model for Coding Geographic Location Coordinates*, International Journal of Scientific & Engineering Research, Vol. 4, Issue 7, pp. 2468-2470, July, 2013.

[13] L. Goldman, A. I. Schafer, *Goldman’s Cecil Medicine*, 24th edition, Elesevier publishing, 2012.

