

Real-time Heart Pulse Monitoring Technique Using Wireless Sensor Network and Mobile Application

Nabeel Salih Ali¹, Zaid Abdi Alkaream Alyasseri², Abdulhussein Abdulmohson³

¹ITRDC Center, University of Kufa, Iraq

²Faculty of Engineering, University of Kufa, Iraq

³Faculty of Education, University of Kufa, Iraq

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ABSTRACT

Wireless Sensor Networks (WSNs) for healthcare have emerged in the recent years. Wireless technology has been developed and used widely for different medical fields. This technology provides healthcare services for patients, especially who suffer from chronic diseases. Services such as catering continuous medical monitoring and get rid of disturbance caused by the sensor of instruments. Sensors are connected to a patient by wires and become bed-bound that less from the mobility of the patient. In this paper, proposed a real-time heart pulse monitoring system via conducted an electronic circuit architecture to measure Heart Pulse (HP) for patients and display heart pulse measuring via smartphone and computer over the network in real-time settings. In HP measuring application standpoint, using sensor technology to observe heart pulse by bringing the fingerprint to the sensor via used Arduino microcontroller with Ethernet shield to connect heart pulse circuit to the internet and send results to the web server and receive it anywhere. The proposed system provided the usability by the user (user-friendly) not only by the specialist. Also, it offered speed and results accuracy, the highest availability with the user on an ongoing basis, and few cost.

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Corresponding Author:

Nabeel Salih Ali,
Information Technology Research and Development Center (ITRDC),
University of Kufa,
Kufa Street, Main Campus, University of Kufa, Najaf Governorate, Iraq.
Email: Nabeel@uokufa.edu.iq

1. INTRODUCTION

The global elderly population is growing, and the general population is aging, therefore, monitoring systems for hospital healthcare are necessary to continually monitor and track the physiological parameters of the patient [1-3]. Modern applications have been presented via wireless technologies to bring forth exciting possibilities in the medical markets [4]-[5]. Whilst, several portable devices are produced to perform monitoring and tracking tasks to the physiological parameters for the patient. These materials include heart rate monitors, pulse ox meters, and blood pressure [6]-[8]. Additionally, the patient can be attached to these instruments via wired and become bed-bound in moving sequentially As well as discrete continuously can appear in the monitoring devices via they have to be disconnected and then reconnected later [9]-[10]. Today, wireless technology has been eliminated all of the time-consuming jobs as well; the patients could be independent of instrumentation and bed [11]-[13].

Wireless Sensor Network (WSN) is one of the standard direction in information communication and technology (ICT) research areas that developed on various technologies such as sensor technology, micro-electromechanical technology and wireless communication technology [14]-[16]. Consequently, several wireless systems have been rapidly increasing primarily for medical applications in the recent years [17].

With using Body Sensor Network (BSN) systems, the life quality for people has been improved via providing different healthcare services such as medical monitoring, memory enhancement, and medical data access communication with the healthcare provider in emergency situations through the Short Message Service (SMS) or General Packet Radio Services (GPRS) [18]-[20]. Healthcare services can be benefited for the patient and their families by providing a remotely gain and monitor physiological signals without the necessity of interruption the healthy life of patient [21].

Smart healthcare possibly vision is produced by several studies in all computer, networking and medical care domains. Researchers have increasingly become interested in improving technical solutions that address problems in healthcare delivery [22]. However, accurately predicting the future of any healthcare domain is a complicated task. Hence, delivery of healthcare services to members of the global aging population poses significant challenges. Moreover, delivery of these services is affected by different situations that require cost cutting for healthcare services [23].

Aminian et al, 2013, proposed health monitoring system to monitor the patient physical parameters for pregnant woman parameters mainly; These parameters are blood pressure and heart rate of the woman and heart rate and movements of fetal by the wireless sensor network; In the proposed system, sent data with short range of frequency by using relay and wireless relay with minimum energy consumption provide quality whilst, this system has some problems, one of these issues the coordinator node that works with battery while the patient forgot to recharge the battery that causes dangerous for the patient life [24]. Likewise, González et al (2014), conducted a new alternative to measure heart rate and body temperature for patient care in real-time settings via combined between Wireless Sensor Network (WSN) and Mobile Augmented Reality (MAR); The discussed work can be extended to involve some improvements such as database implementation with the cloud and more manufacturing specifications for sensors [25].

As alongside, Triantafyllidis (2014), proposed a smartphone healthcare system to measure physiological parameters of the patient by using portable/wearable sensors and monitor the condition of a patient and configured monitoring plans for the health professionals in an individualized manner [26]. Almadani et al (2015), conducted an E-Ambulance framework of smart health monitoring system of patients for the remote professional medical model; The presented method provided a paramedic staff with automatic responses to warnings and suggestions inside an ambulance. But, it lacks to use diverse medical systems over different wireless technologies like ZigBee, WI-Fi, and Bluetooth technologies [27]. On the other hands, a real-time monitoring system for various health parameters of a patient was implemented by Mahgoub and Khalifa (2015).

The measured parameters include temperature and Oxygen that are calculated and transmitted by a computer based on a remote client; There are some limitations of their results such as affecting noise which obtained from sensors, permanent damage to the Light Emitting Diode (LED) sensors, and there is a little bit complicated when calculating the SpO₂ [28]. As well, a new model was proposed by Tamura et al. (2015), to improve team-based healthcare for testing and to monitor the physiological parameters of patients which can be used as a rehabilitation training system. The proposed method included a highly efficient database, unobtrusive monitoring, and interventions by health professionals; Whilst, the system required more testing in a home-based healthcare environment [29]. Akshay and Krishna (2016), designed and presented a healthcare improvement system which can be used to providing higher quality healthcare services in the population of Rural India. The proposed system can be easily carried and rapidly measurement with implemented algorithms; Whilst, the system required helping a doctor to detect abnormal activity and to keep tracking of those particular person/ patient [30].

In this paper, design a system application for measuring heart pulse for the patient and displaying the heart pulse via a smartphone and computer over the network in real time environment. The proposed system using a heart pulse sensor, Arduino Uno microcontroller, Ethernet shield for remote healthcare monitoring for the patients. The system includes several steps such as sensing and reading circuit, processing and transferring signals, and finally connecting to the network to present the results. Additionally, the sensing reading will be presented via computer and smartphone-based applications. The rest of the paper structure as follows: Section 2 highlights the methodology of the proposed system that contains: materials and methods description, implementation steps. Explain system testing as well the results of the proposed system and discussions in Section 3. Section 4 presents a comparison of the heart rate monitoring systems that have been done in healthcare services and applications concerning system performance and results. Besides, the last section offers conclusions and future directions which is Section 5.

2. METHODOLOGY OF THE PROPOSING REAL-TIME SYSTEM

This section presents and describes the methods of the proposed monitoring system that include system architecture defines in Section 2.1, system implementation visualizes in Section 2.2.

2.1. System Architecture

This section presents the electronic circuit design that includes software and hardware requirements as well as methods of the proposed system monitoring. The system aims to measure and analyze the Heart Pulse (HP) of patients. The results are stored in a computer-based application which can be accessed remotely as well as via smartphone application based.

Hardware and software components are required to implement the electronic circuit. These elements were selected based on different criteria namely low cost, availability, and ease of programming. The hardware components needed for the implementation such as Arduino UNO board, amplifier (LM368), filter LBF, Ethernet shield V6, sensors (IR Emitter), and Samsung Galaxy s Duos S7562. Also, the required software components are Arduino program V1.6.0, processing program (V 3.0.1), Android V1.6.0, and Android studio. Figure 1 presents the block diagram of the proposed monitoring system.



Figure 1. Block diagram for the proposed system architecture

2.2. System Implementation

The flow of blood recorded and measured by the number of pulses in one minute whereas heart rate or heart pulse must be measured accurately due to the importance of measuring the accurate heart rate should not be ignored [31]. In this paper, a hybrid scheme between wireless sensor network (WSN) and smartphone application for heart pulse monitoring is proposed. The main purpose of the proposed system is to monitor and check the status of the patient in real-time environment and report the result via computer-based application and smartphone-based application. Figure 2 shows the implementation steps of the proposed system where it involves three stages that are describing in the next subsections respectively (2.2.1, 2.2.2, 2.2.3).

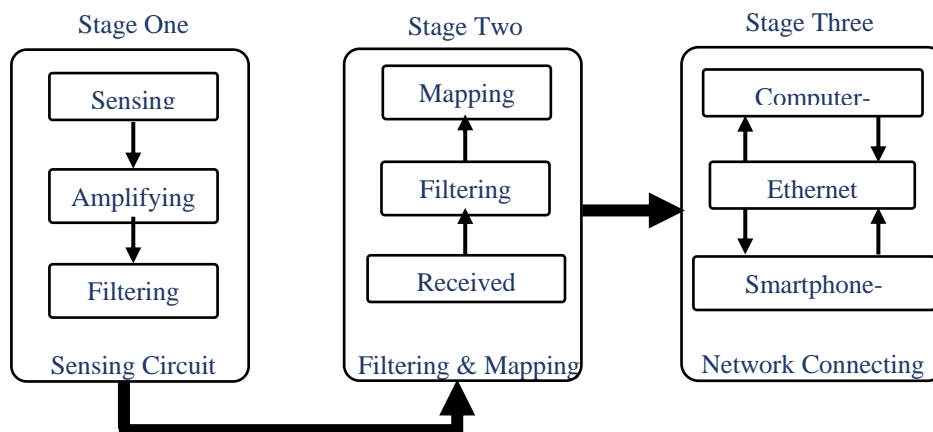


Figure 2. Implementation steps for the proposed monitoring system

In this first stage (sensing circuit stage) the heart pulse will be detected by using the blood racing through veins. Then, the heart pulse will process via amplifying and filtering to be more suitable for the next step. In the second stage (filtering and mapping stage), the heartbeat signal which is received from the previous stage will be filtered again to ensure that it is free of noise. After that, it will be mapping to utilize smartphones and computer devices. The last stage (network connecting) is connecting and display the results of the heart pulse via smartphone or computer devices consecutively.

2.2.1. Stage One (Sensing Circuit Stage)

In heart pulse measuring (sensing) standpoint, the system using sensor technology to detect the blood racing through veins via identifying the heart pulse of a patient and counts the pulses for one minute to get the beats per minute. The sensing process is done by bringing the patient's fingerprint to the sensor (emitters and detectors for infrared) which is included two steps that are (IR Emitter) emitting and sensor diodes to detect and measure the pulse that passes light from one side of the finger as well measuring the intensity of the passed light from the other side via using an IR detector see Figure 3 (A). Also, the second process in the sensing circuit stage has used an amplifier (LM386) to amplifying the pulse that measured in the previous procedure. Where, the received signal amplified enough to be detectable by the microcontroller inputs see Figure 3 (B). Whereas the third process in the first stage is done via using filters (LPF). This process using two stages with low pass filters that removed some unwanted signals, which eliminating some frequencies to suppress interfering signals and reduce background noise see Figure 3 (C). Figure 3 include three parts which are (A, B, and C) to present all steps and processes of the sensing circuit stage.

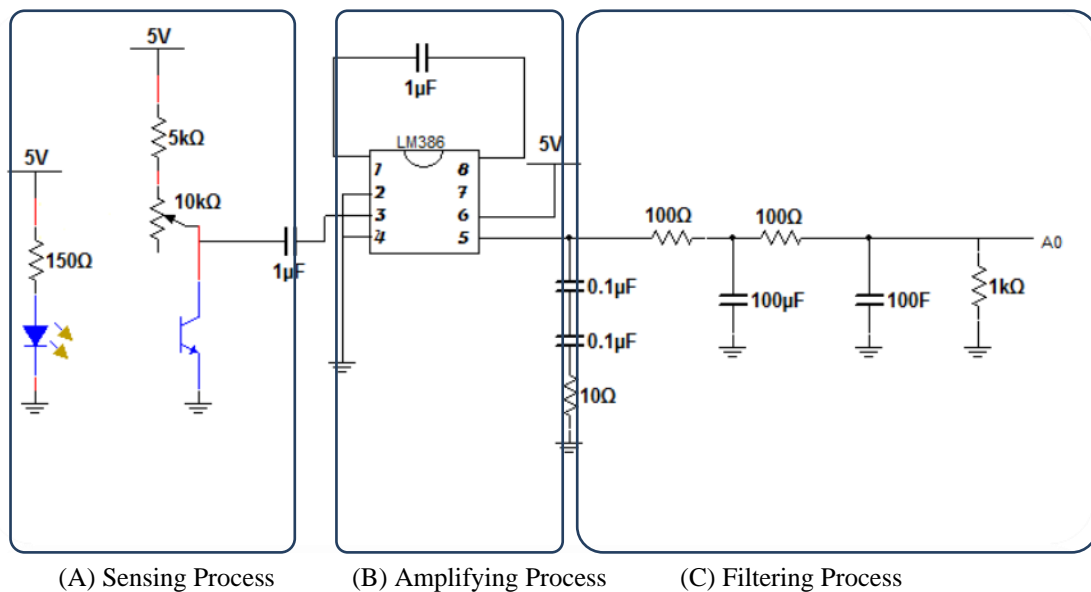


Figure 3. Processes of the sensing circuit stage

2.2.2. Stage Two (Filtering and Mapping Stage)

In this stage, Arduino microcontroller is a platform that performs signal processing received from the sensing signal process in stage one. Arduino received an analog signal from the port (A0) and filtered it from any noise that may disturb the information via implements a digital low pass RLC type of filter. Also, mapping the data and programmed it to supply a heart rate on the desired GUI view see stage two in Figure 2.

2.2.3. Stage Three (Network Connecting Stage)

In the third stage, an Arduino board connecting to the internet by using Ethernet shield based on Wiznet (W5100) Ethernet chip via sending a data over the network to a computer-based application as well smartphone-based application that received signals and displayed. There are two platforms used to present the HP values such as computer-based and smartphone-based applications. From computer end, processing software is used as a Graphical User Interface (GUI) to display the result after set IP address of the browser which it depends on the values of time and amplitude with two dimensions (X-axis and Y-axis). Whilst, the result viewed in a smartphone application by using Android Application that programmed by Android Studio software in Java language.

3. RESULTS AND DISCUSSION

As for mentioned in the previous section, the primary purpose of this system is transferring the heart pulse in the real-time by using IR emitter sensor, IR detector sensor then sends the heart pulse via Ethernet shield. The result has been shown in the Android and computer applications. For testing the performance of the proposed system, the heart pulse of 10 persons with different (age, gender, and status) are recorded. Table

1 shows the expected results of the proposed system brespect to the standard heart pulse which taken from [32]. Figure 4 shows the actual results of ten persons testing with different (age, gender, and status).

Table 1. Expected Results of the Proposed System Testing

No.	Gender	Age	Standard [32]
1	Male	25	95-162
2	Male	23	95-162
3	Female	23	95-162
4	Male	25	95-162
5	Female	51	85-145
6	Male	14	60-100
7	Male	5	75-115
8	Female	70	75-128
9	Male	62	78-132
10	Male	24	95-162

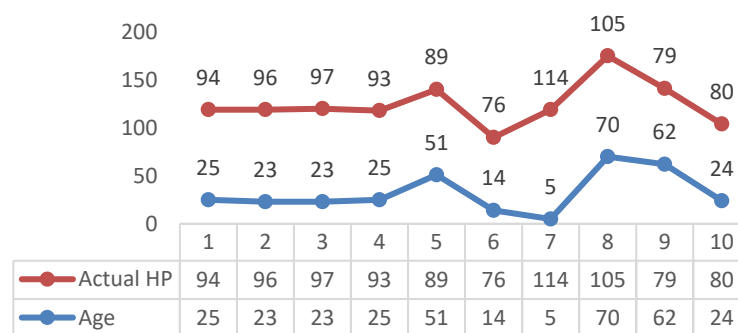


Figure 4. The actual results of ten persons testing with different (age, gender, and status)

The physiological parameters of the human body are usually affected by several factors, such as exercise, body position (for instance, the body position for a short while after standing up quickly), body temperature, and emotions (such as anxiety and arousal). The experiment carries out with a commercial device, and accordingly, we presented an evaluation method based on signal quality and analyzed and tracked the performance of the proposed system in measuring and monitoring the physiological parameters of the patients in real-time settings (see Figure 4). As we can compare between Table 1 and Figure 4, the HP value recorded by the produced system is lower than the standard HP and this standard value is based on the situation of the patient. Also, the conducted system reported results that all lie within the standard values [32]. The presented healthcare monitoring system was evaluated using the results obtained from 10 persons with different ages, gender, and situations (see Table 1). Additionally, the discussed system measured a patient's physiological parameters, namely, HP. The results showed that the proposed system has potential to be implemented as a decision support system in the healthcare field for future research.

4. COMPARISON OF THE PREVIOUS HEART RATE MONITORING SYSTEMS IN HEALTHCARE SERVICES AND APPLICATIONS

Several efforts have been made by researchers on proposing and developing monitoring healthcare systems based on sensor technology to present sustainable medical interventions concerning different metrics such as pure, low energy consumption and real-time feedback. These systems have been introduced to improve the quality of health services and to reduce the total cost of healthcare [33]. Table 2 presents a comparative analysis of previous studies and the proposed system in heart rate monitoring systems for schemes and methods, heart rate parameters, real-time or remote monitoring conditions, and highlights to their main findings.

Table 2. Comparison of the Previous Studies for Heart Rate Monitoring Systems

Research	Year	Method and Scheme	Heart Rate Parameters		Monitoring Conditions		Main Findings
			Normal	Others	Real-Time	Remote	
[27]	2015	smart ambulance system model	✓	✗	✓	✗	Presented E-Ambulance model by providing paramedic staff with automatic responses to warnings and suggestions inside an ambulance [27].
[31]	2015	Smartphone and Wearable Sensors	✓	✓	✓	✗	Smartphone and Wearable Sensors are used to conduct a real-time healthcare monitoring system for remote cardiac patients in healthcare services [31].
[30]	2016	Bio sensors and Arduino board	✓	✗	✓	✗	The real-time bio-signal Acquisition System had several advantages such as is easier for carried at remote locations and acquiring physiological parameters of the patients as well as it quickly and rapidly with the implemented algorithms [30].
[33]	2016	GSM, GPS, Arduino, and Web technologies	✓	✗	✓	✗	Introduced a real-time healthcare monitoring system to improve the quality and reduce the cost of health services. The efficient applications are capable of track, trace, monitor and positioning the patient conditions and locations by using GSM, GPS, and Arduino & web technology [33].
[34]	2016	Camera-based method	✓	✓	✗	✓	A heart rate variability system is proposed, and it was reduced absolute errors of HRV metrics. The proposed plan is comfortable and convenient for remote healthcare monitoring conditions [34].
[35]	2016	Wireless pressure sensor	✓	✗	✓	✗	Discussed healthcare and critical care monitoring system by using a wireless pressure sensor to monitor heart rate sensitively. The sensor has many benefits like speed without delay and distortion [35].
[36]	2016	Hilbert transform in Seism cardiograms (SCG)	✓	✓	✓	✗	Proposed a technique to identify beat of heartbeat detecting timings by using Hilbert adaptive in SCG [36].
[37]	2016	Internet of Things	✓	✗	✗	✓	The authors used the concept of Internet of Things (IoT) to provide the lifeline to people via delivering remotely accessing the data from sensors [37].
[23]	2017	Sensor, Arduino, Wi-Fi	✓	✗	✓	✗	Measuring and monitoring physiological parameters of the patients in real-time settings [23].
[38]	2017	Color facial video	✓	✗	✓	✗	Presented a real-time system to measure and monitor HR based on LAB color facial video space using a web camera [38].
Proposed	2018	Real-Time HP Monitoring System	✓	✗	✓	✗	The proposed system provided the possibility of ease of use by the user (user-friendly) and not only by the specialist also offered speed and the accuracy of the results as well as the highest availability with the user on an ongoing basis, and few cost.

Most previous studies that measured the heart rate of patients in a real-time environment such as [23], [27], [30], [31], [33], [35], [36], and [38]. Whilst, two studies are measured HR remotely by [34] and [37].

On the other hands, regarding heart rate parameters. There are wireless, wired, Bluetooth, internet-based, and webcam communication. Seven previous studies conducted a heart rate in the normal condition like [23], [27], [30], [33], [35], [37], and [38]. Whereas, the works [31], [34], and [36] are presented in several heart rate parameters such as heartbeat timings and inter-beat time intervals in SCG by [36], heart rate variability by [34], Normal HR, Bradycardia HR, and Tachycardia HR by [31].

5. CONCLUSIONS AND FUTURE DIRECTIONS

Monitoring systems for hospital healthcare are necessary to continue monitoring and tracking the physiological parameters for the patient. Advanced applications have been presented via wireless technologies to bring forth exciting possibilities in the medical market. Today, wireless technology has been eliminated all of the time-consuming jobs as well as, the patients could be liberated from instrumentation and bed. In this paper, design a system for measuring heart pulse of a patient and displaying it in a smartphone and computer over the network in real-time settings. The presented method provided the possibility of ease of use by the user and not only by the specialist also offered speed and the accuracy of the results as well as the highest availability with the user on an ongoing basis, and few cost. From the perspective of future work, we intend to develop the conducted system to encompass two directions, first direction is to improve the proposed system to measure heart rate, temperature, Oxygen in the blood and breathing. The second direction target is to enhance the application that performs tracking to the patient physiological parameter by a doctor via sending alarm or notification. In addition to, send an alert to a nearby clinical home via GPS for an emergency situation.

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BIOGRAPHIES OF AUTHORS

Nabeel Salih Ali received his BSc. degree in computer science from the University of Technology (UoT), Baghdad, Iraq, and the MSc. degree in Computer Science (Internet working Technology) from the University Technical Malaysia Melaka (UTeM), Malaysia, in July 2015. He has been working in Information Technology Research and Development Centre, the University of Kufa from 2007 as a member in addition, as a Lecturer at the Department of Electronics and communications (ECE), Faculty of Engineering. His research work in web applications security techniques to improve the security and survivability of computer systems. In addition to, Wireless Sensor Network (WSN), healthcare monitoring systems, Internet of Things (IoT), password encryption, and Software Defined Network (SDN).



Zaid Abdi Alkareem Alyasseri: (b. 1985 Najaf/Iraq) graduated with a BSc in computer science from Babylon University in 2007 and received MSc in computer science from University Science Malaysia (USM) in 2013. The author works as an Asst. Lecturer in Electronics and Communication Engineering Dept. at the University of Kufa-Iraq. He has experience for 10 years in software development and system analysis also he has good experience in many programming languages and database. Authors' research interests are computer vision and image processing, computer graphics processing, programming, and parallel computing.



Abdulhussein Abdulmohson, he was born in Al-Najaf, Iraq in 1979. He obtained the B. Tech. Degree in Computer Engineering from University of Technology, Baghdad, Iraq, 2002. M.Tech. Degree in computer science and engineering from Osmania University, Hyderabad, India Hyderabad, India. He is a lecturer in the Faculty of education at the University of Kufa, Najaf, Iraq where he has been a faculty member since 2015.