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Research paper

An Internet of Things (IoT) Application for Standard Clinical ECG's Monitoring in Real Time Application

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Abstract

Real-time monitoring application of vital body signals gets particular attention in medical research, no exception to the use of IOT applications. The focus of this paper is the acquisition of 12 lead ECG signals from the patient's body and then sending data to the cloud and widely accessible through the Internet instantly. In the measurements process, the device at the patient's side is connected to the receiver application through the Internet by accessing the web server address. At that moment, the data ECG signal is sent to be displayed on the application side. Graph of ECG signals appears on web pages live and continue until the end of the measurement. Medical record system is also applied to this system. By monitoring the ECG signal from the ECG standard instruments can help diagnose heart health in detail. Medical experts can determine the heart conditions and can provide treatment as soon as possible.

Keywords: *IoT, ECG, cloud, internet, web*

1. Introduction

Real-time control and monitoring devices into one focus of research globally. Ease of access, high flexibility, and the demand is one reason the development of studies in this field for a variety of applications. Furthermore, the system is developed to be widely accessible without limited places. This technology is better known as the Internet of Things (IOT). IOT with a device able to connect and communicate with each other through the media multiplatform computer networks, in other words, the IOT is a dynamic network that is integrated with the global network (Santucci, 2010).

IOT has been used for medical purposes in support Telemonitoring systems. Here is one quote from an article "The emergence of the Internet of Things (IOT) - where the physical devices are instrumented to capture and transmit the data (Krishnamurthy et.al, 2016)".

Medical devices acquired the human vital signal, and the data is sent then simultaneously for further purposes. One of the critical parameters that indicate health is the shape of the ECG signal (Rizal & Hadiyoso, 2015) which represents the condition of the vital organs of the heart. In some circumstances, patients require continuous monitoring of both current and long relax anytime and anywhere. Most importantly, patients had ECG machine that can connect to the monitoring application.

In this study developed a system of standard clinical ECG (12 lead) that can be accessed in real-time for cardiac signal monitoring. Starting from the hardware development of low-cost ECG clinical standards on previous work which can only be accessed locally (Hadiyoso et.al, 2015). This development aims to make monitoring more flexible and can be used in global applications by utilizing the internet. With this system, medical experts and patients can consult with each other without any restriction.

Some Researchers have made IOT for monitoring system specifically to monitor human vital signal. Some of the research done in real time and offline. Chiu and Wu (Chiu & Wu, 2011) developed a real-time for Body Area Network (BAN) wireless electrocardiography (ECG) monitoring system based on 3-lead ECG's. The electrical signal from each electrode is sent wirelessly to a PC to be reconstructed ECG signal intact.

Another study by Sung et.al, present real-time IOT multisensor system for aquaculture (Sung et.al, 2014). Environmental parameters such as dissolved oxygen, temperature and pH sent serially to the server via ZigBee and displayed on the remote computer. The system has different sampling frequency characteristics with the ECG monitoring the ECG signal that the signal has to be sampled continuously with high frequency.

Research by Spanò et.al, implementation of IOT on ECG monitoring for multi-patient (Spanò et.al, 2016). The focus of research on the development of low-energy devices 3 ECG leads and seamless integration with the smart home system. (Gupta et.al, 2016), to realize real-time monitoring system health parameters in the web application network localhost. The paper did not discuss how to access through the global Internet network.

In our previous research, we developed the IOT system for multi- patient's ECG monitoring (Nurdin et.al, 2016). The device used is a 3 ECG leads and the ECG for displaying data File.txt Admin will upload the result of the data by the patient's account.

In previous research, the researchers developed ECG system based on three lead system. In some conditions, a standard 12 lead ECG is needed to observe the heart condition in detail. In this paper, we present a system of medical standard ECG (12 leads) connected to the Internet cloud through seamless network design and support applications in real-time. Doctors, medical personnel, and patients can make the observation of ECG signal simultaneously and consult through the application. There are also medical records to save the patient's medical history can be accessed at any time.

The paper is organized as follow; Section II provided literature review about IoT and the methodology are presented in Section III. Implementation of our proposed system is presented in Section IV. Testing scenario and Discussion will be explained in section V, and the Conclusion of the paper is presented in Section VI.

2. Literature Review

2.1. IoT Concept

Internet of Things is a new concept that integrates applied engineering in various spheres of life in any form via wireless or wireline connection. IOT allows everything to interact and work together with the application for a specific purpose (O. Vermesan et.al, 2013).

IOT will combine real, digital and virtual domain so that the difference becomes biased. IOT concept allows everything connected and can be accessed anytime, anywhere and anyone over the Internet Protocol. One of the systems that can be developed in IOT Platform is a wireless sensor network in the field of health (e-health). This concept gave birth to a new paradigm that is the Internet of Things Medical (IoMT). IOT support in the modern health sector can be utilized for telemonitoring, telemedicine, telesurgery, medical records, supply drugs, doctor consultation and more.

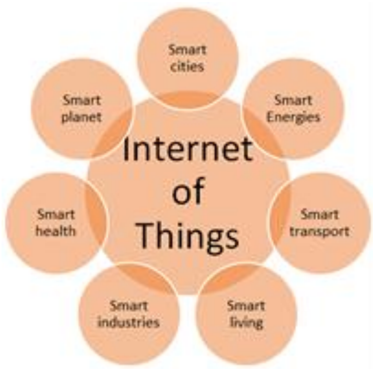


Fig 1: Internet of Things in the context of smart environments and applications (IERC, 2011)

2.2. Client-Server

The concept of client and server on the network computers are widely used for data collection applications, data storage, and data sharing. In practice, the process on the client and server applications performed separately on different devices, on the client side in the form of a Graphical User Interface (GUI) to simplify the interface to the user and on the server side in the form of a command to handle client requests. The client-server architecture will enable distributed network that can be accessed by many users are connected.

In this study, the client application connects directly to the ECG device for transporting authentication and forwards the data to the server. The server receives a request from a client and gives authorization for communication. In detail, the process flows from client to server described in the implementation.

3. Research Methodology

The research consists of three main subsystems they are ECG instruments, client-server applications and user applications. The complete design of the system in this research is shown in the figure 2.

The basic design of ECG instruments is based on Einthoven triangle theory as described in (Tompkins, 1993). From the development of Einthoven theory, we will get a complete ECG signal representation then called ECG 12 leads, which consists of bipolar leads (I, II, III), unipolar leads (aVR, aVL aVF) and precordial leads (V1-V6). The portable ECG's hardware employ instrument amplifier by INA118, analog filter using Op-Amp, level shifter and MCU to convert the analog to digital signal, multiplexing process then sent the binary data to the sever. The number of samples data on each lead is 100 S/sec. Power source for ECG's hardware get from two 16850-type battery.

In order to communicate with the server, the system needs a client PC as gateway. To run the process on the server, this research employs servers with specifications: Ubuntu 16.04 OS, 2GHz CPU, 40 GB HDD and 2GB RAM. PC client is also responsible for authorizing it to servers to send data to the server. In offline mode, the server will check the suitability of the data (patient ID and data formats), then authorize the client to send serial ECG data is to be processed and stored in the database based on the ID and the measurement time. Data storage can be accessed at any time by the concerned parties. In real-time mode, the user can perform direct observation of patient ECG signals through the internet cloud on the web portal.

Testing scenarios for system reliability are display ECG signal on graphs, Quality of Service (delay and load test) and application capabilities for data storage. The applications that used for QoS testing are Wireshark and Web Stress Tool.

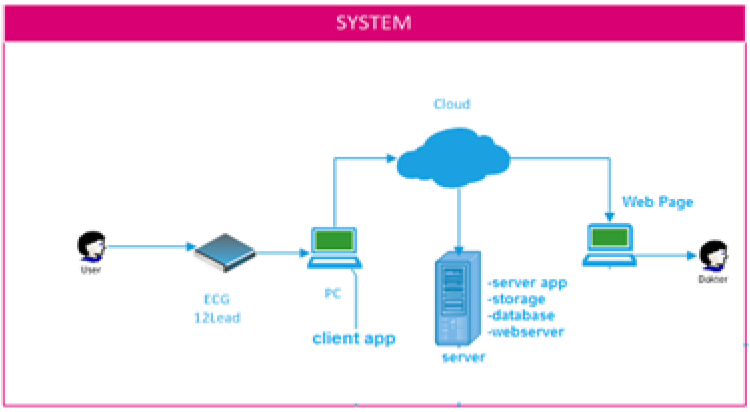


Fig 2: System Design

3.1. Implementation

The proposed system can be seen in Figure 2. ECG's hardware consists of 12 analog front end (AFE), MCU and power source can be seen in figure 3 ECG device and a PC are on the patient's side act as a client. In the cloud, there is a server for authorization settings, web servers, and data storage based on java application. Interested parties may make observations through a web portal in real time or offline. The system is implemented two-way so that the patient and monitoring staffs (doctor or medical expert) can communicate.

Fig. 3: ECG's Hardware

4. Results

In this section, we will explain the testing scenario which has been described in the methodology section, results and discussion after the system successfully implemented. Tests were done at the time the system is running in real-time and offline.

4.1. ECG Graph

Graph of the ECG signal of the patient displayed on a web page through www.ekgram.com. Figure 4 shows a graph of the ECG signal leads. The signal shape is accordance with the basic theory consists of P, Q, R, S and T wave. ECG machines can be concluded successfully acquired signals then the application can be represented in a graphical form that can be used for signal analysis.

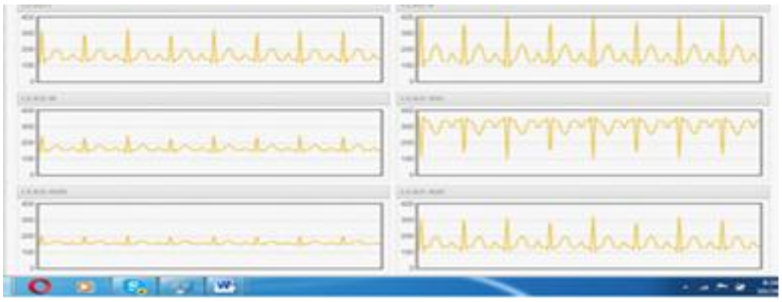


Fig 4: An Example ECG's Graph on Web Page

4.2. Delay

The delay is one important QoS parameters in real-time applications. Based on ITU-T forum on QoS Performance requirements for Data (Telemetry) Realtime service, the maximum tolerance delay on real-time data applications is <250ms. Delay testing was done on internet access speeds of 0.5 Mbps, 2 Mbps and 4 Mbps using Wireshark application. Of the 100 times, the measurement obtained on average a delay of 35.3ms (0.5 Mbps), 16,8ms (2 Mbps) and 15,9ms (4 Mbps) so that the system can be categorized as a real-time application in accordance with the requirements of the maximum delay. The higher the speed of Internet access that is used, then the delay becomes smaller due to the large bandwidth of data processing time becomes shorter. The test results of delay analysis and sample Wireshark testing for each scenario can be seen in Figures 5 and 6.

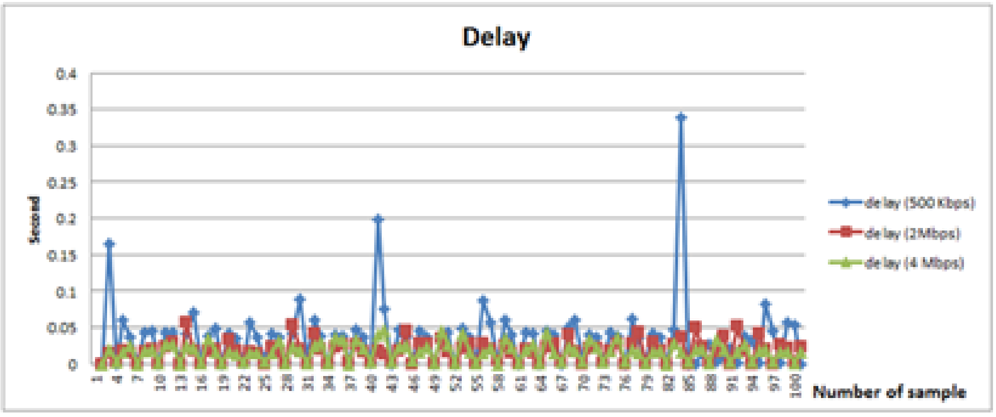


Fig 5. Delay for Each Scenario (100 Sample)

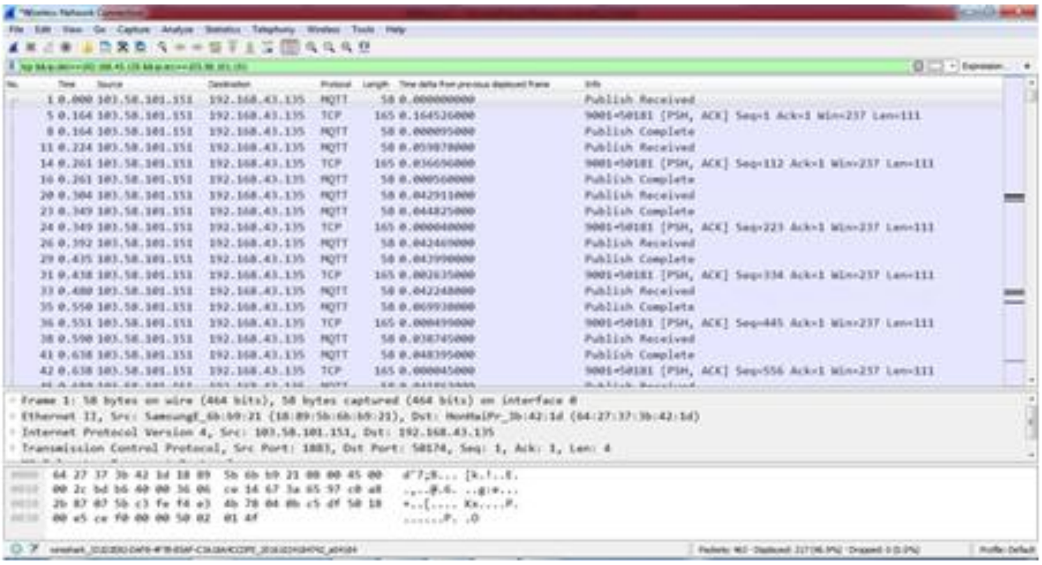


Fig 6. Network Analysis on Wireshark

4.3. Web Server Load Test

We measured the server's ability to determine the number maximum of users can access the web without error. We used a web stress testing software with a variety number of the user.

From this test, the web server can serve up to 500 users simultaneously (see figure 7) accessing www.ekgram.com without error. More and more users then expand data traffic on the server, effect on increasing delay the process so that the graph is shown on the web to be slow and some of the sampling data is not recorded on the server.

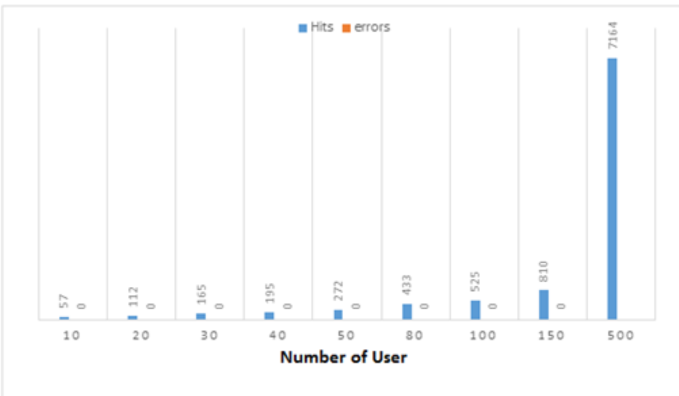
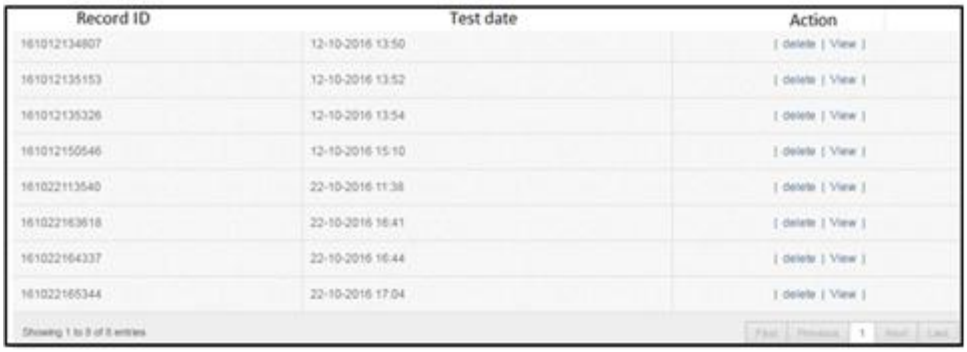


Fig 7: Web server load testing using Web Stress Tool

4.4. Medical Record

An application of medical data must be equipped with the data storage to determine the patient's medical history. The system provides patient ECG raw data storage on servers with a maximum capacity of 40 GB. Under conditions of work and device is connected to the Internet, automatically ECG patient data is stored based on a patient's identity and the measurement time (see figure 8). Through the menu view as shown in Figure 8, then recording signals can be displayed.



Record ID	Test date	Action
161012134807	12-10-2016 13:50	[delete | View]
161012135153	12-10-2016 13:52	[delete | View]
161012135326	12-10-2016 13:54	[delete | View]
161012150546	12-10-2016 15:10	[delete | View]
161022113540	22-10-2016 11:38	[delete | View]
161022163618	22-10-2016 16:41	[delete | View]
161022164337	22-10-2016 16:44	[delete | View]
161022165344	22-10-2016 17:04	[delete | View]

Showing 1 to 8 of 8 entries

Fig 8: An Example of Medical Record

5. Discussion and Conclusion

The testing results show that the proposed system has worked properly. ECG signal acquisition results can be displayed properly on a web page in accordance with the original signal. Meanwhile obtained delay <250 ms for all access speeds tested. The result shows that the system qualifies as a system in real-time. From the server load testing, the system is capable of handling 500 users without any significant error. The system performance gives an indication of the system can be used for many users simultaneously. Sent data can be stored in a database so that patient data can be accessed at any time. The developed system is able to display ECG signals both online and offline. This makes it easy for users to analyze ECG signals at any time. With the availability of signals from 12 leads then the more detail information obtained in making the diagnosis. There are two issues that are not discussed in this study. Firstly, the client application is not equipped with software for automatic ECG signal analysis. The ECG signal analysis is performed manually by the physician. The second is data security issues for the authorization and the resilience of the data against attack or noise. Data security and privacy issues will be the focus of further studies.

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