Design of Telemedicine System Based on Mobile Terminal

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Abstract – Nowadays, there are a lot of handled devices such as smartphone and tablet PC which provide an opportunity to add more applications to the mobile devices which in turn can save the time of the patient to report to the health practitioners. As a new medical method, the remote medical monitoring system is gaining more attention in providing a rapid diagnosis to patients. For instance, this system can help to save the life of the patients who are in remote and rural areas where there is poor transportation for the patients to go hospitals at a related time. This study suggests a kind of remote medical monitoring system which is based on Mobile Terminal and General Packet Radio Service which allows operation of wireless telemedicine systems deliverance medical personnel and patient from a static site. The remote medical monitoring system is composed of three parts specifically mobile remote medical monitoring unit, monitoring center, and the management system. In this exertion, a telemedicine system protocol is aimed and tested. The results of the study display that this system works speedily with low cost and approachable to any user compared to other systems such as telemedical cardiac system.

Index Terms – Mobile Terminal Telemedicine System; Android based systems; General Packet Radio Service; Transmission Control Protocol/Internet Protocol; User Datagram Protocol Electrocardiogram.

1. INTRODUCTION

Mobile medical is based on the grounds of biomedicine, computer science, communication technology, and many other applications. Data transmission, computer hardware, software technology, and other closely integrated high-technologies are hot research topics in the field of telemedicine in recent years. They offer one continuous monitoring of physiological parameters and study the physiological function of patients in different ways [1].

Compared with traditional healthcare, telemedicine provides timely and costless health services in the society [2]. Mobile medical systems mainly consist of physiological parameter monitoring, data transmission, wireless data communication, and control and display units [3] [4] [5]. But many hospitals begin the exploration of "anywhere and anytime" mobile healthcare by which its requirements are an intelligent terminal that sets signal acquisition, processing, and analysis functions as one of the mobile platforms. The use of this technology is embraced by different scholars. For instance, Abdullrahim and Coster (2016) used universal General Packet Radio Service (GPRS) network to achieve wireless data transmission and SCM as the control of original data to transfer patient information to the hospital care platform for analysis and later the information sent back to the doctor. However, this model has a limitation on the medical data exchange [7].

Currently, various scholars use different medical algorithms for patient's diagnosis and early detection and monitoring of the vital signs such as Electrocardiogram (ECG), Blood Pressure (BP), and SO2 [8]. Several surveys have recommended monitoring systems that can measure a variability of bio-signals and be responsible for QRS detection and arrhythmia classification, real-time ECG classification algorithm and heart rate unpredictability measurement [9].

Compared to this designed model, GPRS improves the access and connection compared to the existing models because its coverage area is larger and the operation speed is higher than other models. Moreover, its performance is high without delay. Mobile terminal telemedicine system is designed to the extent that its security is high and safe [10].

This study is based on the Android platform and GPRS technology to design a mobile terminal telemedicine system [11]. The study uses android operation systems and C programming for simulation on the terminal to achieve the scene of physical data collection and storage. It results in the quick and underlay signal transmission of data from the patient to health monitoring center and doctor in order to act promptly where abnormal signals are detected [12]. This system can be used to monitor pre-data analysis of the patients which can be quickly diagnosed to provide timely support. Furthermore, it is used with existing domestic network resources to help patients in remote areas to get timely treatment.

The rest of this paper is organized as follows; section 2 presents related works. Section 3, present the proposed model. Section 4, provides simulation results and discussion. Section 5, provides concluding remarks of this work.

2. RELATED WORK

Conceptually, telemedicine started around the 1960s [13] after the invention of the telephone systems and the fax machine as a mean of communication [14]. According to Yamada at al (2015), information technology has improved healthcare to the patient at "anytime" and "anywhere" to provide emergency health services to the patient's point-of-care. Emergency ambulances are used to transfer patients to the hospital under the care of the nurse on emergency duty [16]. However, currently, modem wireless telecommunication such as GPRS and satellite technologies offers a flexible operation of wireless telemedicine systems, liberating the medical attendants or the subject observed from being bound to stationary locations [17].

Telemedicine has been applied in various scenarios with understaffed medical practitioners to utilize the availability of manpower, minimize the cost of patient transportation to the hospital and shorten the delay time of consultations to the patients [18]. To intensification the mobility of the doctors, the global system for mobile (GSM) communication mobile telephone network was cast-off for connecting the server [19]. But here the main challenge was that the coverage network area and speed of the data transmission were below 3.4kps minimum transfer rate.

Taiwan administrative zone used IEE of 802.11[20] standard with satellite technology together with positive based on the Frequency Division Multiplexing (OFDM) transmission architecture, Mobile Medical has been implemented Link [21]. At present, some advanced wireless technologies such as domestic 3G technology and their applications delay patients' diagnosis and inhibit patients to have enough time for checking their condition. Research indications that the application of embedded technology to medical devices can reduce the costs of medical and treatment equipment. Furthermore, these technologies work quickly and save time. For instance, the 32-bit processor has a large memory and high power which make quick and powerful data processing and analysis.

The intelligent terminal design using embedded technology has become a real deposit in the standard. In this regard, Department of Electronic Engineering at Beijing Institute of Technology made embedded microprocessors named XScale PXA270 which has developed a mobile embedding core to CDMA technology telemedicine system. This system provided mobile medical research incorporating embedded technologies in a reference direction [22] [23].

Feasible foreign mobile medical research group focused on how to make full use of wireless technology to provide patients with a reliable, accurate and portable solution. The project was named Brain Korea 21 project. In this project, researchers used broadband and 3G network technologies to establish "anywhere and anytime" mobile terminal telemedicine system. However, most of the research work on these systems are in experimental stages with low promotion among the medical and health stakeholders [24][25][21].

Zhejiang Computer Science department at Zhejiang University established a mobile healthcare system by using universal GPRS network to achieve wireless data transmission whereby SCM was used as a control center. In this system, original data was transferred from the patient to the doctor through hospital care platform. However, it operated slowly due its low capacity and power [26].

3. PORPOSED MODELLING

System requirements

The design of the proposed model consists of the patient's terminal, remote monitoring (central remote server), and management units which are connected by the network module, as shown in Figure 1.

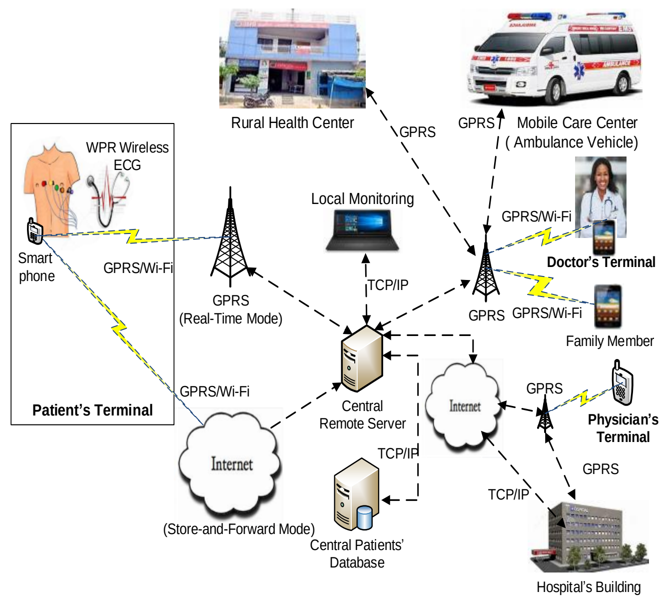

Figure 1: Architecture of the proposed telemedicine system

Patient's Terminal

The patient wears the WPR wireless ECG-sensor which transmit the signals to the smartphone using automatic arrhythmia detection algorithm and smartphone transmits the ECG signals via GPRS to the base for the mobile. The data can be transmitted in two forms which are either a real-time data mode or store-and-forward mode. The doctor receives recorded ECG signals and makes a diagnostic evaluation for the precise patient.

Central Remote Server

This receives and stores the vital signs in the central patient's database and displays the body processes signals to the doctor's terminal via the TCP protocol for study and estimation. Also, it permits remote access for nurses and physicians to obtain vital signs via a web-based application interface over the internet to observe these data using their own devices. After diagnosing the vital signs information, the doctor can respond by MMS message to the patient [19]. The message has medical assistance and/or a list of control commands to the mobile-care device for resending the abnormal case's vital signs data. Likewise, the central remote server may alert the family member in case of abnormalities and call the mobile care center to offer transport to the patient with emergency attention to be taken to the nearby rural center for medication.

Rural Health Center

A rural general hospital is a minor hospital, related to a district general hospital, but where a detailed classical of training and staffing permits the facility of specific healthcare services to a people in the area which is remote and rural. The rural health center provides a referral to patients who require emergency and special treatment.

Family members

Family members are required to get information about a patient's condition from the doctor. They are responsible for supervising the medication and contacting the nurse or doctor in case of the emergency. It is important to involve family members in the healthcare systems due to the fact that family participation in healthcare process improves clinical decision making to the patient and controls undesirable outcomes such as preventive harms. However, there is the time when these members are not fully involved in the healthcare systems, something which leads to poor provision of medical services to the patients.

Physicians/Doctors

Physicians or medical doctors are leaders of the medical care team. They are primary healthcare providers to the patients. They are responsible for patients' diagnosis, surgery, therapy, disease treatment, and conditions control. They have the responsibility for patient's medical treatment coordination from beginning to end by analyzing the patients' symptoms and conditions and managing their care for the best results and recovery.

Nurses

Nurses are caregivers who assist doctors and give medication to patients where required. They play significant roles in hospitals, clinics, and private practices. They are responsible for the follow-up and control of the patients' development. They connect patients and doctors during the treatment process.

Ambulance Mobile care center

Ambulance vehicles are a central part of emergency medical services which aim at assisting critical ill patients to avert life-threatening complications in seriously injured cases [27]. They help in transporting patients to health centers. There is communication between health providers and doctors through GPRS network in the ambulance vehicles.

Local Monitoring center

Local monitoring center is used to monitor the operating system. It alerts when there is a fault and monitors information related to the patient in the central server.

Wi-Fi Security

In Telemedicine systems, security is one of the main challenges. Wi-Fi is by far, the most used wireless protocol and has the best security features [28]. Since WEP can be cracked very easily, people use mostly WPA or WPA2 to secure their networks [12], [29]. WEP uses the Rivest Cipher (RC4) algorithm to provide data confidentiality while CRC-32 is used for data integrity with very simple encryption logic use.

WPA was introduced by the Wi-Fi Alliance with the aims of security enhancements such as authentication, access control, message integrity, replay prevention, message privacy, and key distributions. WPA provides the user authentication and it also controls access with EAP (Extensible Authentication Protocol). IEEE 802.1x standard provides port-based access control to WPA. WPA uses TKIP (Temporal Key Integrity Protocol) to address the issues within WEP. TKIP makes use of a per-packet key, which is able to dynamically generate a new 128-bit key. TKIP is able to defend from replay and weak key attacks.

System Protocol

A most important part of the design is system protocol. In this work, TCP protocol is used. TCP and UDP protocols are used for data transfer and internet connection between medical devices which supporting the treatment.

TCP

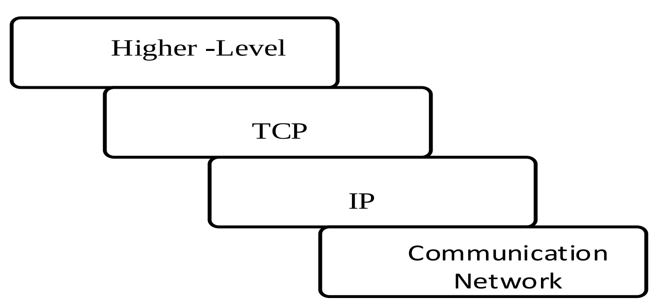

Figure 2: TCP Architecture

TCP is significant and most used network protocol in communication system [20]. Furthermost Internet applications are using this protocol such as peer-to-peer file sharing, world wide web (WWW), File Transfer Protocol (FTP), e-mail and streaming applications. The TCP turns into a layered protocol architecture evenhanded beyond a basic Internet Protocol which suggestions a structure for the TCP to send and receive variable-length segments of information enclosed in internet datagram "envelopes as shown in Figure 2.

UDP

UDP is another type of transport layer protocol which is defined for use with IP network layer protocol, as indicated in Figure 3.

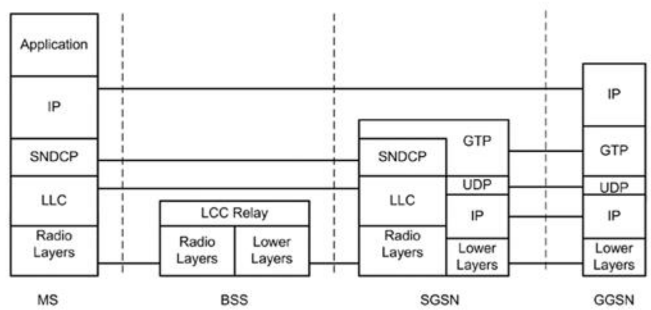

Figure 3: GPRS protocol stack [30]

It is another protocol to TCP which offers a limited quantity of services in the network where data are exchanged between computers which use IP. Like TCP, UDP divides data into packets called datagrams and transmits them from one system to another. Unlike TCP, UDP is based on a connectionless protocol that means one end can send a load of data in packet forms to other end and that may be the end of the connection between them. Its stateless feature helps to save processing time for servers that need to answer small queries to a large number of clients. It is very convenient for applications that require efficient and fast transmission of data such as a game. Using UDP, multiple messages may be sent from one device to another as chunks of packets. It is faster than TCP. UDP provides a port number that helps to distinguish various users' requests and also it has checksum facility which verifies the information arrived at the receiver intact. UDP sends packets individually whereby these packets are checked for integrity only if data arrive in the receiver. The UDP header size is 8 bytes and consists of four field's length which are source port, destination port, UDP length, and UDP checksum, with 2 bytes each.

GPRS network

In the proposed system, GPRS is used as communication means. GPRS is designed to provide a better network architecture for data communication. GPRS based data networks offer continues network connection and deliver billing based on the volume of data sent rather than the time of connection. Furthermore, data rates supported by GPRS (56–117 Kbit/sec.) are quite sufficient for most of the embedded applications. The typical system architecture of a GPRS based on remote data access system is shown in Figure 4. Remote equipment being monitored is connected to the GPRS network using a GPRS modem. It communicates with a central monitoring server that may be connected on a GPRS network or any other PDN. GPRS modem is a SIM-enabled device that can be interfaced with the system using a number of options like serial or USB. Such devices have internally implemented TCP/IP stack that helps to handle data communication as per packet data protocols. They support AT commands for configuration and operation.

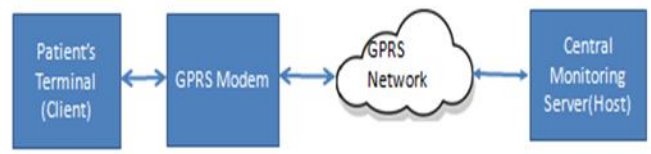

Figure 3: Architecture for GPRS based System

GPRS network provides more than one option for network setup and thus makes easy for selection of more application requirements, as shown in Figure 5 and Table 1.

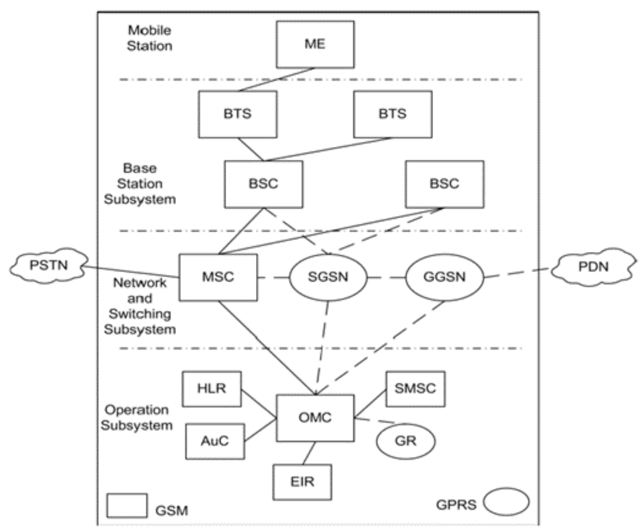

Figure 5: GPRS network architecture [30]

Table 1: GPRS Network Elements

Network Element	Description
ME	Mobile equipment
BTS	Base transceiver station
BSC	Base station controller
MSC	Mobile switching center
SGSN	Serving GPRS support node

GGSN	Gateway GPRS support node
OMC	Operation and Maintenance Center
HLR	Home location register
AuC	Authentication center
GR	GPRS register
EIR	Equipment identity register
SMSC	The short message service center

GPRS module

GPRS is the most used network for wireless coverage. Therefore, in this study, the GPRS network was selected to achieve wireless communication. GPRS module is a machine communication network which connects various routers that provide a packet transfer service. This is a remarkable difference between GPRS and GSM networks. Compared with GSM network, GPRS network can utilize wireless resource more effectively and it is suitable for the burst data transmission business of a long time and large flow rate. With multi-slot bonding and high-speed coding scheme, GPRS rate theoretically is up to 171kbps. GPRS network transmission provide has different advantages, as shown in Figure 6 [10].

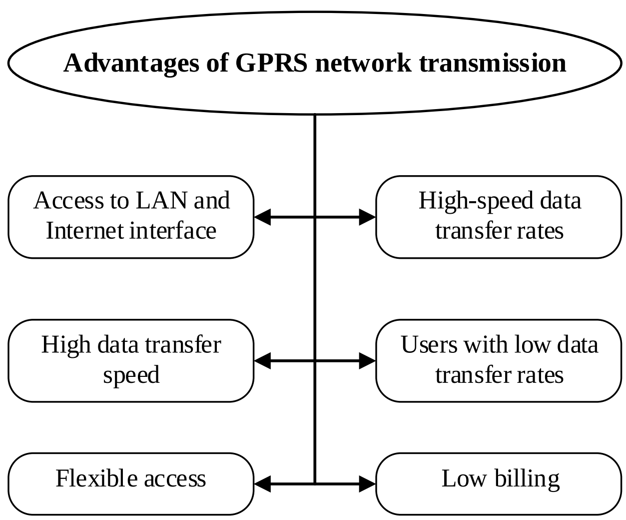

Figure 4: Merits of GPRS Network Transmission

4. RESULTS AND DISCUSSIONS

As shown in Figure 1, by using the smartphone on the terminal, the patient can monitor his/her blood pressure, ECG, SO2, and RESP in real time. The ECG and RESP signals are sampled with ARM system-on-chip ADC at 200 Hz and 20 Hz. Blood pressure is collected from the corresponding sensor board through serial ports. Software filtering is performed on ECG signal and RESP signals. Then QRS (ECG) detection, heart rate computation, respiration rate computation, premature beat detection, and medical alert rules are executed in real time by applying some specific algorithms. A doctor views and diagnoses monitored data displayed on the ECG. After the diagnosis, a doctor should inform the patient on the treatment process. Mobile terminal telemedicine system is suitable in case the patient has stress and helps him/her to call for an assistance. The mobile terminal telemedicine was implemented with Visual C++. It receives data from multiple terminals. The number of connection is limited only by the bandwidth of the network and the computation ability of the CPU.

All the received data are saved on disk in real time, but 8 waveform channels at most are displayed on the supervision screen simultaneously. A test was performed for verifying the scalability of the system against the number of connected terminals. In the first test, the workstation started with no client connected. On one occasion the panic situation is stated and the link has been established with the doctor's mobile phone using GPRS, the mobile phone of the patient transmits a one-minute sample of ECG signal via the mobile cellular network. The transmission of the ECG signal be able to reflect similar to the transmission of a digitized voice signal over a mobile cellular network.

The resulted parameters and signals are continuously sent to the workstation through the network and saved in the terminal.

Software

The demonstration and steps for an authorized user to cooperate with the received patient's data over application program was developed using C# language. The interface design offers most general functional requirements as shown in Figure 8.

Users access to the system through a login page designed to work with the one-time password system. The system main menu is composed of a list of available functionalities. The number of displayed functionalities depends on the user's typology such as general practitioner, cardiology, dermatologist specialist, tutor, and consultation. A special account which provides access to the configuration pages is enabled for the system administrator.

A patient opens the patient's management page. This page provides a form with which it is possible to add and edit patient information. Only accredited users as the tutor or secretary have full access to the functionalities. The patient's management page contains medical report page, which appears after opening the first page. For each patient, the system displays an interactive form where the patient's name, general practitioner, and dermatology specialists are highlighted. The Medical Record page provides the list of treatment plans and the list of therapeutic annotations. The general login processes are presented in Figure 9 to Figure 15.

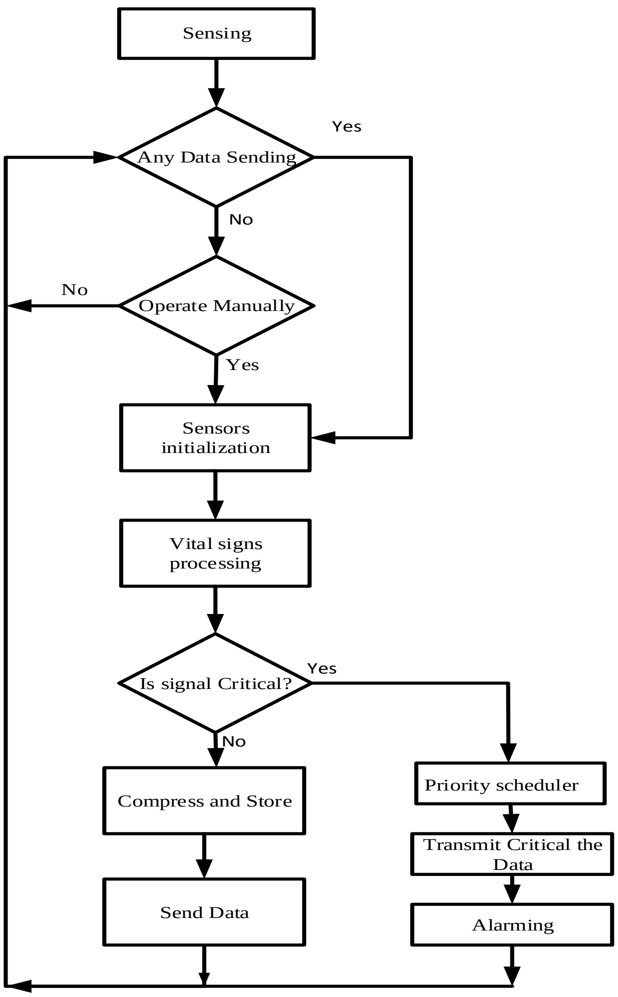

Figure 8: Flow Chart for Mobile Unit Working Mode

Figure 5: User authentication page

Figure 6: Screenshot of the developed interface main page

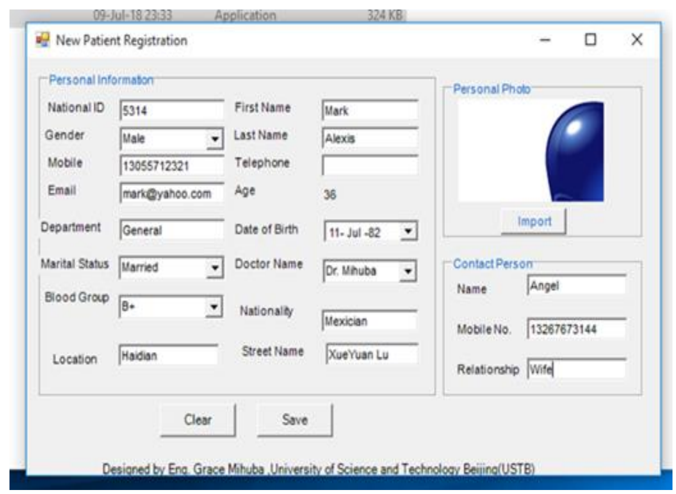

Figure 7: Add new patient screenshot

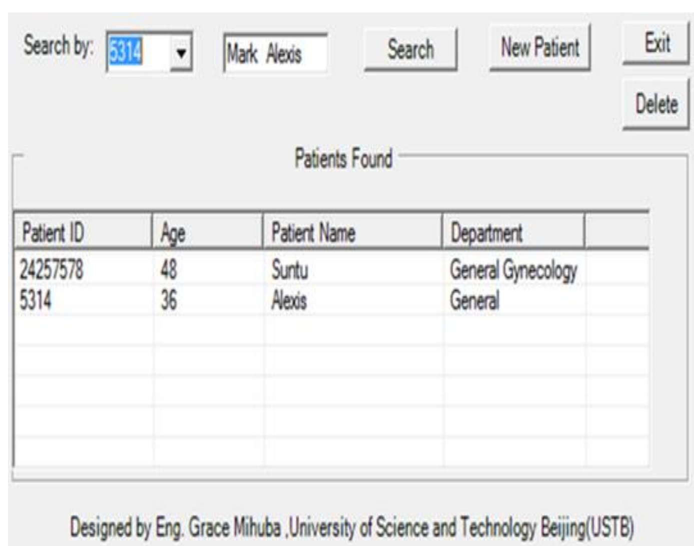

Figure 8: Screenshot of how to search

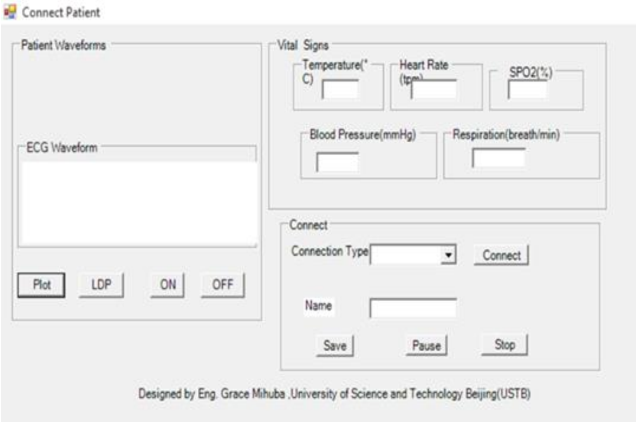

Figure 9: Displaying a patient's vital signs

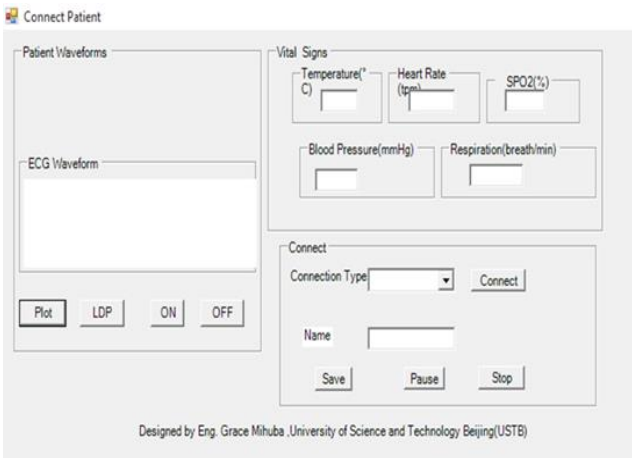

Figure 10: Displaying patient's vital signs home monitoring

Figure 11: Medication form

5. CONCLUSION

In this study, a design of a telemedicine system propose is used to run operation tests of the system by doing a simulation of the signal on the mobile based terminal of telemedicine system in which all physiological vital signs are transmitted to the remote medical server through both cellular networks in emergency case and internet in normal case for long-term monitoring. The results shows that the proposed system presents a friendly server-based interface for medical staff to observe immediate vital signs of patients for remote treatment. Comparing this system with other systems which are mentioned in the introduction, the proposed system integrates sensor, processing units, and communication system which makes it more portable, convenient and modern.

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