# XBee Wireless Blood Pressure Monitoring System with Microsoft Visual Studio Computer Interfacing

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*Abstract -* **In this modem age, everything comes with wireless, portability and ease to use. Technological developments of wireless devices and systems can also be found in medical field. This has allowed physicians and healthcare providers to connect remotely with patients and give a proper care. Wireless technology in medical field has become readily apparent. E-health and m-health (using mobile devices) provide the most effective patient care and medicine dosage. Human prefer an easy way to use the medical device without any medical knowledge. This paper proposes a blood pressure monitoring device with wireless system which links to computer and records the reading automatically. So, an automated blood pressure measuring device will be used in this project and XBee is chosen to the blood pressure measuring device wirelessly to the computer. Two XBee will be used in this project, one is to transmit and another one is to receive the data. Each XBee will be connected to a microcontroller build-in PIC to process the reading obtained from the blood pressure measuring device. The received blood pressure reading will be recorded. An interfacing system which is created by using Visual Basic will record the reading into a database and show the result to the users.**

*Keywords: Blood pressure; XBee*

## I. INTRODUCTION

Blood pressure refers to the pressure of the blood in arteries. Blood pressure happens when heart pumps blood around the body through the arteries, by contracting and relaxing [1]. So it is a measure of how forcefully of the heart pumping blood around our body [2]. Each measurement of blood pressure will always give two numbers, for example 120/80 mmHg. The first (higher) number is called the systolic blood pressure and the second (lower) number is the diastolic blood pressure. So the 120 means systolic blood pressure (higher number) and 80 for diastolic blood pressure (lower number). The blood pressure is measured in millimeters of mercury (mmHg) [3].

The most common technique for monitoring the blood pressure is using the stethoscope in classic way by most of the doctors in medical environment. Recently, a lot of medical equipments have stepped into the high technology world. So, easier way to monitor blood pressure has been published. Nowadays, several companies come out with digital blood pressure monitoring devices, which will automatically measure the blood pressure without any knowledge of how to measure blood pressure. Users just need to follow the instruction provided with the device. The automated blood pressure monitoring device solves a lot of problems that most doctor face, such as white coat effect. Doctors can now differentiate white coat hypertension from essential hypertension by using blood pressure monitoring systems [4]. Users also can measure their blood pressures anytime, at home or workplace. Along with the evolution of technology, the data of blood pressure measured can be recorded and put into the computer to analyze. One of the problem of the latest blood pressure devices which can be found in medical area is when the patient has "white-coat-effect". This will result in fault and inaccuracy of blood pressure reading from high-risk patients and pregnancy. As the latest blood pressure devices need cable connection to computer in order to send the data and record in the computer automatically, the main concept of this project is to cancel out the cable connection between the computer and blood pressure sensor by using the XBee. The data will be recorded in the computer with graphical user interface to let the patients easily seem their blood pressure readings and when the time when blood pressure is taken.

## II. LITERATURE REVIEW

### A. Blood Pressure

From the paper research and online information, the average blood pressure reading for a healthy person is 115/75 mmHg, which are 120/80 mmHg and 105/65 mmHg during day time (awake) and night time (asleep) respectively. For the hypertension threshold, the average blood pressure reading is 130/80 mmHg, around 135/85 mmHg while awake and 120/75 mmHg while sleeping. At night time (sleeping) average systolic and diastolic blood pressure should both be at least 10% lower than day time (awake) average [5]. High blood pressure does not only occur for hypertension threshold, but it may also occur depends on emotions,

exercise, talking, using tobacco and caffeine products [6]. There are several reasons that cause the hypertension of a patient and give a fault or inaccurate blood pressure reading. So "white coat effect" is discovered and it can cause a patient to overtreatment. This is both real and common in the management of hypertension. Researchers and doctors found out that blood pressure reading in medical environment or doctors' offices were consistently higher than the blood pressure reading taken in home [7]. Patients with white coat hypertension may respond differently to antihypertensive drugs and having more side effects.

According to a paper written by O'Brien E, most of the "white coat effect" founders based on the Ambulatory Blood Pressure Monitoring (ABPM) system to find out that some patients might show more tension. This situation will cause the blood pressure to become high which is hypertension, but actually the patients have normal blood pressure. During daytime and night-time period, blood pressure measurement at home is devoid of the white coat effect [8]. It is important to acquire an accurate blood pressure reading allowing physician to make efficient treatment to patient especially pregnant woman. A correct blood pressure reading enables the doctor to give efficient drug treatment to the patient and pregnant woman especially for pregnant woman who have high blood pressure, which is called 'pregnancy-induced hypertension' or 'gestational hypertension'. This phenomenon will influence the blood pressure reading. With the correct reading of blood pressure and knowledge of the condition of pregnant woman, doctor will check whether the medicines taken to lower blood pressure are still safe or not, by considering the risks of pregnant woman and baby very carefully [9].

### B. Types of Blood Pressure Measuring

There are two ways to measure blood pressure, namely classical type which uses stethoscope and automated type which uses high technology. The classical type of measuring blood pressure is quite complicated when compared to automated type. The classic type requires the cuff to be placed around the upper arm at same height as the heart and inflated with the bulb until the cuff is filled with air. This may cause the patient to feel uncomfortable and the artery will close. Doctor will then use the stethoscope to listen to the Korotkoff sound and slowly release the air in the cuff. Systolic blood pressure is the first Korotkoff sound produced when the pressure of cuff is same as the pressure produced by heart. As the air in the cuff is further released, the sound will become quieter and quieter, until the cuff stops limiting blood flow and to allow smooth flow of blood. This silent Korotkoff sound will be diastolic blood pressure.

For the automate type blood pressure measuring, the patient just only need to wear the cuff at same height as the heart. The cuff is connected to a device. The device will inflate the cuff to a certain level when the ON/OFF button is pressed. Then it will deflate automatically. At the same time it deflates, the sensor in the device will detect the pulse and pressure of blood in artery and the information will show on display screen [10].

### C. Monitoring of Blood Pressure

According to a paper written by, Michel Burnie and Guido Grassi, both ambulatory blood pressure and home blood pressure monitoring provide more reliable and reproducible information on blood pressure. The blood pressure values obtain by Home Blood Pressure Monitoring appears to be more closely related to target organ damage. So measurement of out-of-office blood pressure is recommended.

According to a paper with title "European Society of Hypertension Practice Guidelines for home blood pressure", home blood pressure monitoring (HBPM) is a valuable tool in the daily management for hypertension patients and pregnant woman. It also shows that HBPM should be performed daily at least 3 and preferably 7 days before visiting the doctor. Duplicated measurements should be obtained in the morning (before drug intake if treated) and in the evening (before eating), with two measurements per occasion (1–2 min apart). Blood pressure values measured on the first monitoring day should be discarded. HBPM helps to improve compliance with long term treatment, hypertension control rates and conditions where strict blood pressure control is mandatory (high-risk patients and pregnant woman). It's also important for the physician to know the daily blood pressure of a patient in order to make an efficient treatment and decrease the unnecessary drug intake for the patient which may lead to side-effect. Daily blood pressure reading also serves as a further reference for physician and enables physician to whether there is any improvement on the patient's condition or not.

There have several types of blood pressure devices such as ambulatory measurement of blood pressure and self-measurement of blood pressure which is also called home blood pressure measurement. Ambulatory blood pressure (ABP) monitoring will measure the patient's blood pressure at every 20-30 minutes over 1 day. The patient can undergo normal activities, including sleeping. This method of measuring blood pressure can only be used for the person in certain circumstances such as pregnant women and elders. Then the result of blood pressure reading over one day will be given to the physician for further analysis. It can be used to get an accurate reading on the patient [11]. Self-measurement of blood pressure, also called home blood pressure monitoring is portable and it is easy to use by everyone. It uses oscillometric method to obtain the blood pressure. The cuff is worn on the upper arms of the patient and the position need to be at the same level as the hearts. "START" button is push and the cuff will inflate and deflate automatically. Then the reading can be read on the display or the reading will be sent to the computer through the connection from blood pressure monitoring device to computer.

## D. Sensor and Ways to Get Blood Pressure Reading

Nowadays, blood pressure device also uses latest technology to measure our blood pressure by using the built-in pressure sensor. Different blood pressure devices use different pressure sensors. Most of the pressure sensors use Microelectromechanical systems (MEMS) purposely invented to be a small size and has low power consumption. MEMS means micro-electro-mechanical-system; it is the technology of very small devices that are made using the techniques of microfabrication. A lot of sensors have implemented MEMS technology into the design as it is small and light-weight [12]. Oscillometric method uses an electronic pressure sensor with a numerical readout of blood pressure. In most cases, the cuff is inflated and released by an electrically operated pump and valve, which may be fitted on the wrist (elevated to heart height), although the upper arm is preferred. Initially the cuff is inflated to a pressure in excess of the systolic arterial pressure, and then the pressure is reduced to below diastolic pressure. Once the blood flow is present, but restricted, the cuff pressure will vary periodically in synchrony with the cyclic expansion and contraction of the brachial artery. The values of systolic and diastolic pressures are computed from the raw data, using an algorithm.

## E. Analysis of the Bluetooth Technology

Nowadays, there are different types of wireless communication. Bluetooth is one of the common ways used in a lot of electronic gadgets such as laptop, mobile phone, mouse and keyboard. Bluetooth is a wireless technology with global standard for expanding range of devices and services. It was invented by telecom vendor Ericsson in 1994. Bluetooth also uses unlicensed radio transmission to transmit and receive data in the speed of 2.4GHz to 2.485GHz. Bluetooth is mainly developed to be used in personal area network (PAN). PAN is defined as a network of devices in the range of a person which can communicate with each other [13]. Piconet and Scatternet are two different topologies through Bluetooth communication occurs. Piconet has only 8 nodes (devices) connected where one is master and one or more than one are slave devices. Scatternet forms when multiple piconets overlap [14].

## F. XBee Technology

XBee is a specification for a suite of high level communication protocols. It is created for control and sensor networks based on the IEEE 802.15.4 standard. It is created by the ZigBee Alliance which runs in low data rate with low power consumption and small packet devices. It is a transceiver, which means it can transmit data wirelessly and it can also receive data wirelessly. XBee is intended to be simpler and low cost because low cost allows the technology to be widely used in wireless control and sensor networks. XBee is Series 1 (802.15.4), comes with the firmware to create connection for point to point or star

network. ZigBee devices have three types: ZigBee Coordinator, ZigBee Router and ZigBee End Device [15].

## G. WiFi Technology

WiFi has become a dominant standard for WLAN (wireless LAN). It is mainly developed to operate as a wireless Ethernet. WiFi is an open-standard technology which allows the wireless connectivity between equipment and local area networks [16]. It runs in unlicensed radio spectrums. WiFi can be set as open access to allow public to connect to it. The range of the WiFi is about 50 to 150 meters. The encryptions of the WiFi are WEP based on IEEE 802.11 and WPA based on IEEE 802.11i. Nowadays, those two encryptions can be hacked easily so it is not recommended to be used in personal area network [17].

TABLE I.     COMPARISON OF XBEE, BLUETOOTH AND WIFI

|  | **XBee** | **Bluetooth** | **WiFi** |
|---|---|---|---|
| Data rate | 20, 40, and 250 Kbits/second | 1 Mbits/second | 11 & 54Mbits/second |
| Range | 10 – 100 meters | 10 meters | 50 – 100 meters |
| Frequency band | 868/915 MHz, 2.4GHz | 2.4GHz | 2.4GHz, 5GHz |
| Power Consumption | Very Low | Medium | High |
| Max number of cell nodes | More than 65000 | 8 | 2007 |

## H. X-CTU

X-CTU is a free multi-platform application designed to enable developers to interact with Digi RF (radio frequency) modules through a simple-to-use graphical interface. It includes new tools that make it easy to set up, configure and test XBee® RF modules.

XCTU includes all of the tools a developer needs to quickly get up and running with XBee. Unique features like graphical network view, which graphically represents the XBee network along with the signal strength of each connection, and the XBee API frame builder, which intuitively helps to build and interpret API frames for XBees being used in API mode, combine to make development on the XBee platform easier than ever.

## I. Visual Studio

Microsoft Visual Studio is an Integrated Development Environment (IDE) developed by Microsoft. It is used to develop computer programs for Microsoft Windows, as well as web sites, web applications and web services. Visual Studio uses Microsoft software development platforms such as Windows API, Windows Forms, Windows Presentation Foundation, Windows Store and Microsoft Silverlight. It can produce both native code and managed code.

Visual Studio includes a code editor supporting IntelliSense as well as code refactoring. The integrated debugger works both as a source-level debugger and a machine-level debugger. Other built-in tools include a forms designer for building GUI applications, web designer, class designer, and database schema designer. It accepts plug-ins that enhance the functionality at almost every level, including adding support for source-control systems (like Subversion) and adding new toolsets like editors and visual designers for domain-specific languages or toolsets for other aspects of the software development lifecycle (like the Team Foundation Server client: Team Explorer).

Visual Studio supports different programming languages and allows the code editor and debugger to support (to varying degrees) nearly any programming language, provided a language-specific service exists. Built-in languages include C [18], C++ and C++/CLI (via Visual C++), VB.NET (via Visual Basic .NET), C# (via Visual C#), and F# (as of Visual Studio 2010[19]).

## III. METHODOLOGY

The reading from the blood pressure device needs to be taken out and sent to the computer via XBee. The most complicated part is to get the reading from the blood pressure device. Further investigation of the blood pressure device is needed in order to find the reading data store.
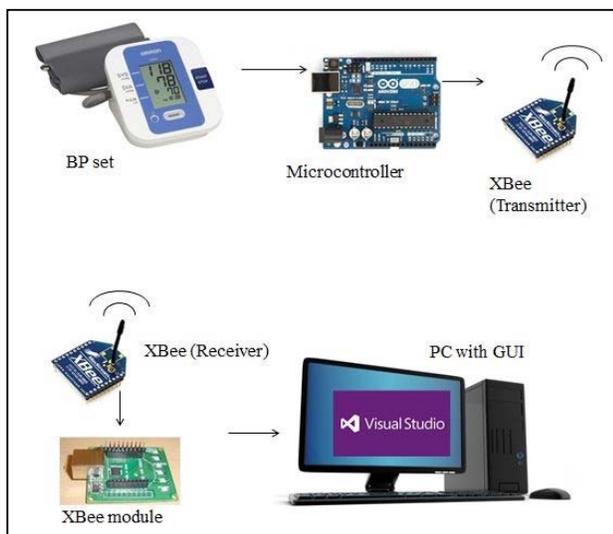


Figure 1.    Block Diagram of the Concept.

Figure 1 shows how the wireless blood pressure monitoring system with computer interfacing works. Arduino Uno will be the main part of getting the blood pressure reading from the device. The data point in the blood pressure device will be connected with the Arduino Uno analog input. The IC chip will be programmed with a code that sends the input data from analog port via XBee to another XBee that is connected with a computer. Visual Studio will be used to write a program to record the data

received from the XBee into the computer. Normally blood pressure device can only store up to certain limit of readings because the memory of the device is limited. Computer has large memory if compared to the blood pressure device, so it can store a lot of readings and perform calculation of the average blood pressure of a user. Visual Studio 2014 will be used to create a computer interface that can record the data and create a table of blood pressure reading. It also will arrange the readings by time and plot a graph for the user and physician to recognize easily.

Before the use of XBee, it needs to be configured by using the X-CTU program. X-CTU is used to update or change the firmware on the radios. X-CTU can switch XBee radio from router to coordinator or switch between API and AT modes. FTDI drivers will be installed to let the computer talks via serial to the XBee module board.
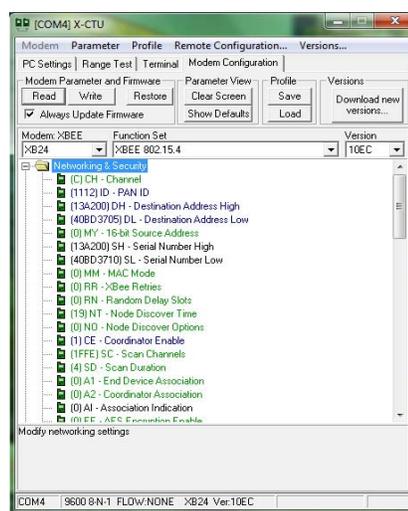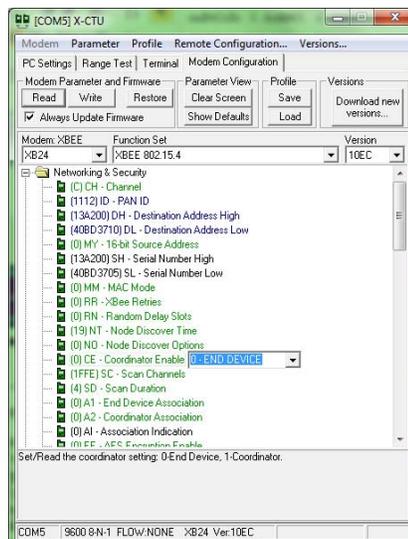


Figure 2.    Coordinator XBee Function.



Figure 3.    End Device XBee Function.

Two XBees are needed to run as the wireless protocol sends the blood pressure reading obtained by Arduino to the computer. In order to use those two XBees, it is required to programme one of the XBees into a coordinator device and another as the end device. In figure 2, the first XBee is configured as coordinator and XBee in figure 3 is configured as end device. Those two XBees need to have same PAN ID in order to send and receive data in the same ID. SL and SH are Serial Number Low and Serial Number High respectively. Those serial numbers had been configured and programmed inside the XBee chip by the factory. SL and SH are used to set the DH and DL, which is Destination Address High and Destination Address Low respectively. From figure 2 and 3, the two XBees were configured with the destination address of each other. The XBee will send the data to the DH and DL set and receive the data from there. The code that is written in Visual Studio will detect the virtual serial port which is made by FTDI driver to receive the data.

## IV. CONCLUSION

Wireless blood pressure monitoring system will bring advantages to physician, which allows physician to record the data automatically. Wireless blood pressure monitoring system is also more portable without the wire connection to the computer. Graphical user-interface helps user to recognize their blood pressure easily. An application that can install in IOS and Android system will be written for the user to synchronize to their blood pressure reading recorded in the computer. This type of the blood pressure is strongly suggested for home use.

## V. FUTURE IMPROVEMENT

It is very inconvenient for the patients to visit and show their blood pressure report to their physician. In order to solve the problem, a user friendly interface can be developed to allow patients to contact their physician directly, conclude their blood pressure readings and send those readings to the physician. There are a lot of blood pressure devices in hospital but doctor needs to go around and monitor each patient's blood pressure. In the future, a program can be developed to recognize different blood pressure reading from different blood pressure monitoring devices used in hospital or large medical area. Furthermore, an IOS or Android application can also be developed to

allow user to gain access to their blood pressure reading anytime and anywhere.

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