Development of online blood pressure monitoring system using wireless mobile technologies

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Introduction. Blood pressure is the force of blood pressing against the walls of arteries. Blood pressure varies within each heartbeat. The highest value is during heart contraction and it is called systolic pressure. The lowest pressure is when heart relaxes and is called diastolic pressure. Blood pressure is one of the most commonly measured physiological parameters. Usually it is measured using oscillometric method when cuff is placed around patient's upper arm, electric compressor is used to inflate it and electronic pressure sensor is used to detect blood flow.

It is known that blood pressure varies during the course of day and may change in response to stress, drugs, disease, exercise and momentarily from standing up. Some people experience high blood pressure only when they visit doctor's office. This condition is called "white-coat syndrome" [1]. In these cases patient may need to wear ambulatory blood pressure monitor for 24 hours [2] that can take blood pressure measurements every 30 minutes.

Current ambulatory blood pressure monitor systems have several drawbacks. Patient must stay in hospital outside of its usual environment. If used at home patient needs to remember to regularly take measurements and write them down. In automated systems the measurement data still needs to be somehow sent to the doctor. Solution to these problems would be a system that can take measurements and send them to the doctor automatically.

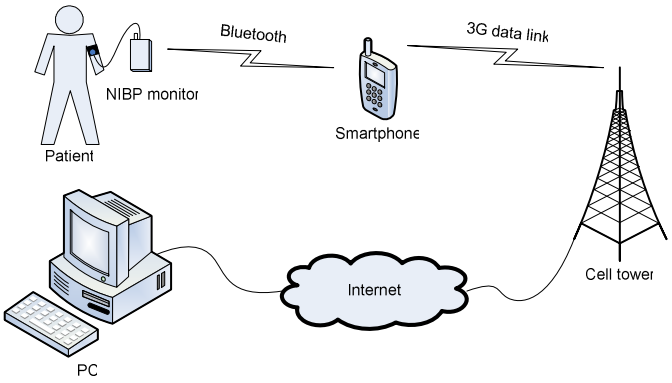

Fig. 1. Wireless blood pressure monitoring system concept

In attempt to solve these problems we developed system where patient's blood pressure is measured automatically and transferred to the doctor's computer over wireless internet. Having experience in creating similar system

for transmitting electrocardiograms using mobile phone [3] it looked promising to use the same concept in making such system for blood pressure monitoring. Our idea was to use Bluetooth for short range wireless transmission and mobile phone technologies for long range transmission of blood pressure measurement data over the internet. System concept is shown in Fig. 1.

Wireless blood pressure monitoring system. Main components of the system are wireless portable blood pressure monitor, smartphone with software for making measurements and personal computer server with software for receiving and storing blood pressure data. Measurement data from monitor device is sent wirelessly to smartphone using Bluetooth link. Smartphone is connected to the Internet using mobile phone technologies such as GPRS (General Packet Radio Service), EDGE (Enhanced Data rates for GSM Evolution), HSDPA (High-Speed Downlink Packet Access) or other. Using this internet connection measurement data from smartphone is sent to personal computer which is permanently connected to the internet using ordinary cable connection. Data flow in the system is shown in Fig. 2.

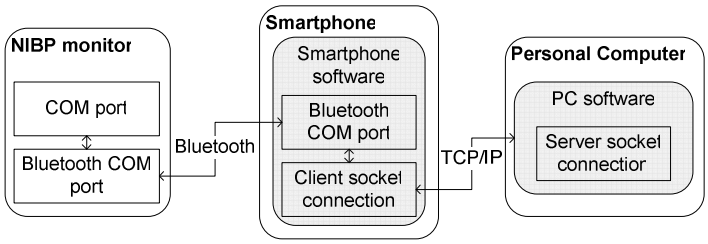

Fig. 2. Data flow in the system

Hardware is built around MedLab's OEM NIBP (Non Invasive Blood Pressure) module [4]. It contains compressor, pressure sensors and microprocessor for measuring blood pressure. Communication with module is done using serial interface. Hardware also contains Free2Move Class 1 (100 m) Bluetooth module, LiPo battery (3.7 V, 1.3 Ah) and various circuits for USB, LEDs, power supply, power converters, etc. All these components are fitted inside plastic casing of size that can easily fit into pocket. On the front side of the device there is on/off switch, Bluetooth antenna, cuff hose line tubing and USB connector (see Fig. 3). There are 4 LEDs that indicate on/off status, Bluetooth connection, battery charging and USB activity. Fully charged wireless NIBP monitor can operate for at least 24 hours taking measurements every 30 minutes.

Software for the smartphone (see Fig. 4) is running on Windows Mobile operating system. It has several tasks. It must connect to NIBP monitor device and send control and configurations commands to it. Connection is established over reliable encrypted Bluetooth link. Before connecting smartphone must pair with device's Free2Move Bluetooth module using predefined PIN (Personal Identification Number). Any smartphone with correct PIN code can connect

without any additional configuration. Another connection smartphone must make is internet connection to remote PC server. Then it can transfer blood pressure data to from monitor device to PC. If the internet connection is not available smartphone can be used in autonomous mode as mobile blood pressure monitor and display data on screen. When not actively used for configuration or other purposes the blood pressure monitor program can run at background without interfering with other functions of mobile phone.

Fig. 3. System hardware. Wireless NIBP monitor

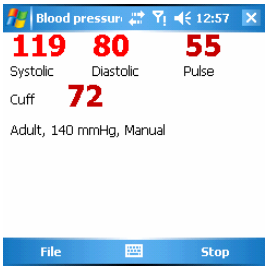

Fig. 4. Smartphone software

Server software on the PC waits for incoming connections from mobile blood pressure monitor. It is used to store and represent all the pressure measurements received from mobile measurement units. We developed only very simple program to test the system. It can only do basic functions like display received data and save it. In the future more complicated software can be developed that can graphically display blood pressure changes over the course of day for many different patients or be integrated in larger telemedicine system.

Results and conclusions. We have developed mobile wireless blood pressure measurement system prototype that uses Bluetooth and mobile phone to transmit data. It attempts to solve some of the problems experienced in taking regular measurements of patients at home. The system can be used in telemedicine as individual 24 hour blood pressure monitor or it can be used by

doctor on a visit to patients. There is still a room for improvement in terms of device size and ease of use. In future if the system concept is found useful it can be improved by integrating mobile phone directly into blood pressure measurement unit and avoid using smartphone as middleware.

References

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4. NIBScan OEM Module Data Sheet. Medlab GmbH, 2008.

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We have developed a new type of system for monitoring patient's blood pressure online. System consists of digital NIBP monitor device, Windows Mobile smartphone and personal computer connected to the Internet. Wireless mobile blood pressure monitoring device has NIBP module, Bluetooth transmitter and battery. It periodically measures patient's blood pressure and transmits measurement data to smartphone using Bluetooth wireless link. Smartphone has software for viewing data and controlling device. It is also connected to the Internet using cell phone technologies and retransmits data to personal computer. Server software on personal computer is used for blood pressure data storage and review.