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A BIOTELEMETRY SYSTEM WITH MICROCONTROLLER AND INTEGRATED WEB SERVER IN WIRELESSIEEE 802.11B TCP/IP NETWORK

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ABSTRACT

In this study, we have developed a biotelemetry system using IEEE 802.11b WLAN technology, a WebNet and a WebRJS-PIC adapter card. This multichannel system is able to transmits measured oxygen saturation, blood pressure, body temperature and heart rate values of a patient to any recipient. Our system has two major advantages different from traditional systems. The first advantage is that by considering traditional systems, faster data rate is provided in our system using IEEE 802.11b WLAN technology. While special transmitters which require special receivers are used in traditional systems, any TCP/IP supported device can be used in our system as system receiver. This is the second major advantage. Because of small dimensions and low weight of the transmitter unit, this unit gives only a little disturbance to patients. This system is low cost, useful and improvable.

Keywords: Biotelemetry, Wireless LAN, IEEE 802.11b, Internet Gateway, Web Server.

KABLOSUZ IEEE 802.11B TCP/IP AĞLARINDA MİKRODENETLEYİCİ VE TÜMLEŞİK WEB SUNUCU KULLANILAN BİR BİOTELEMETRİ SİSTEMİ

ÖZET

Bu çalışmada IEEE 802.11b kablosuz yerel alan ağ teknolojisi, bir WebNet ve bir WebRJS-PIC arabirim kartı kullanılarak bir biotelemetri sistemi geliştirilmiştir. Bu çok kanallı sistem bir hastadan ölçülen oksijen saturasyonu, kan basıncı, vücut sıcaklığı ve nabız sayısı bilgilerini herhangi bir alıcıya gönderebilmektedir. Sistemin geleneksel biyotelemetri sistemlerine göre iki önemli avantajı bulunmaktadır. Bunlardan ilki, sistemde IEEE 802.11b kablosuz yerel alan ağ teknolojisinin kullanımı ile geleneksel sistemlerden çok daha hızlı veri iletişim hızı sağlanmasıdır. Geleneksel biotelemetri sistemlerinde özel alıcılar gerektiren vericiler kullanılırken, geliştirilen sistemde alıcı olarak herhangi bir TCP/IP destekli cihazın kullanılabilmesi sistemin ikinci önemli avantajıdır. Verici ünitesinin hafif ve küçük boyutlu oluşu hastalara çok az rahatsızlık vermektedir. Sistem düşük maliyetli, kullanışlı ve geliştirilebilirdir.

Anahtar kelimeler: Biotelemetri, Kablosuz yerel alan ağları, İnternet geçit yolu, Web sunucu.

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1. INTRODUCTION

Biotelemetry refers to the utilization of telecommunication technology for medical diagnosis, treatment, and patient care [1-2]. Recent technological advances have enabled the introduction of a broad range of telemedicine applications, such as tele-radiology [3-5], tele-consultation [6], tele-surgery [7], remote patient-monitoring [8]–[10], and health-care records management [11] that are supported by computer networks and wireless communication.

In these studies, wireless transmission technologies such as satellite links, GSM, GPRS have been used for data communication. The use of satellite communications has been demonstrated [12]–[16], but it requires expensive equipment, dedicated links, and skilled operators. Mobile cellular networks like GSM, GPRS are realized low cost data communication world wide but these technologies have low bandwidth [17-19].

Furthermore, special transmitters and receivers had been designed for every study. These devices use special signal sense, coding and transmission technologies, hence transmitter signals can be achieved by only compatible receivers. These technologies, whose coding and transmission techniques aren't accepted widely, aren't standardized and advanced significantly. This situation causes incompatibility, low bandwidth, low sequrity and unwidespreading problems [1-5].

In this study, for transmission line, which is important component of biotelemetry systems, IEEE 802.11b WLAN is used. In the system, by using WebNet and WebRJS-PIC technology with IEEE 802.11b, wireless communication is realized among electronic devices. The WebNet module has hardware components such as CPU, RAM, ROM and ethernet interface. In additional, this module supports ARP/RARP, PPP, UDP, TCP, DHCP, HTTP, FTP, SMTP, Telnet, DNS, MIME, SNMP communication protocols as a network computer and this module controls a microcontroller on integrated main board [20].

With developed this biotelemetry system, biological information of a patient can be observed with whatever TCP/IP supported and authorized mobile receiver as wireless without using any external hardware component. This situation provides highly mobility both patients and their doctors. In this way, except the special situations under medical observation patients needn't stay in hospital. Also the doctors, who want to observe biological information of the patients, needn't stay in specific monitoring points, neither. The doctors can access information of patients using a TCP/IP supported and internet connected device. We have considered that a lot of cities will be compatible wireless network in the near future, so the patient is assumed within the wireless network in this system. For using outside of wireless network boundaries, patient's information can be transmitted by a GSM network using a GPRS modem.

2. IEEE 802.11 WIRELESS LOCAL AREA NETWORKS AND IEEE 802.11B

The most commonly used and known Wireless Local Area Network (WLAN) standard today is the IEEE 802.11. IEEE 802.11 is the most mature wireless protocol in the unlicensed band of 2.4 GHz for WLAN communications, tested and deployed for years in corporate, enterprise, private and public environments. Definition of the IEEE 802.11 started in 1990 and in June 1997, the IEEE (Institute of Electric Electronic Engineers) finalized the initial standard for WLANs: IEEE 802.11. This standard specifies a 2.4 GHz operating frequency with data rates of 1 Mbps and 2 Mbps.The initial IEEE 802.11 standard defines three types of physical layer specifications: Direct-Sequence Spread Spectrum (DSSS), Frequency Hopping Spread Spectrum (FHSS), and infrared (IR) [21]. In the late 1999, the IEEE released two supplements to IEEE 802.11 standard: IEEE 802.11a and IEEE 802.11b. IEEE 802.11b is a data rate extension of initial IEEE 802.11 DSSS providing data rates up to 11 Mbps in 2.4 GHz ISM band and IEEE 802.11a defines a new physical layer operating up to 54 Mbps in 5 GHz ISM band using Orthogonal Frequency Division Multiplexing (OFDM) [22,23]. In 2003, IEEE released a supplement to initial IEEE 802.11 standard namely, IEEE 802.11g. IEEE 802.11g provides data rates up to 54 Mbps in 2.4 GHz ISM band using OFDM [24].

IEEE 802.11 networks consist of four major physical components, namely, distribution system (DS), access point (AP), wireless medium (WM), and stations. DS used to interconnect a set of basic service sets (BSSs) and integrated local area networks (LANs) to create an extended service set (ESS). AP has station functionality and provides access to the distribution services, via the WM for associated stations. WM used to implement the transfer of protocol data units (PDUs) between peer physical layer entities of a WLAN. Stations contain an IEEE 802.11 conformant medium access control (MAC) and physical layers (PHY) interface to the WM [25].

The basic building block of an IEEE 802.11 network is called the basic service set (BSS), which consists of a group of stations that communicate with each other. Communications among different stations take place within a fuzzy wireless area called the basic service area (BSA), defined by the propagation characteristics of wireless medium. A station is free to move within the basic service area, but it can no longer communicate directly with other members of BSS if it leaves the area. The logical architecture defines a network's operation. The logical architecture of IEEE 802.11 standard that applies to each station consists of a single MAC and one of multiple PHYs defined in the standard. IEEE 802.11 covers the lower layers of the OSI model, and specifies the Physical and the MAC layers (Fig. 1) [21].

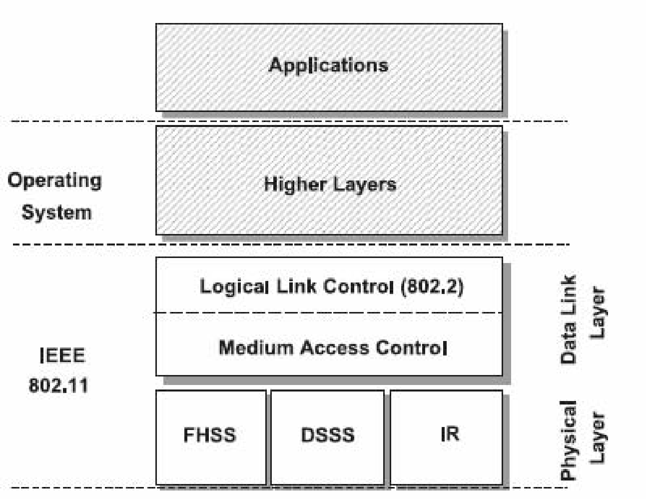

Figure 1. IEEE 802.11 protocol stacks.

The IEEE 802.11 networks can be classified into two major categories based on two different flavors of BSSs as follows. The independent basic service set (IBSS) is a standalone BSS with no backbone infrastructure, consisting of at least two wireless stations. Stations in an IBSS communicate directly with each other and thus must be within direct communication range. This type of network is often referred to as an ad-hoc network or ad-hoc BSS because it can be constructed quickly without much planning. Infrastructure BSS networks are distinguished by the use of an access point. Access points are used for all communications in infrastructure networks, including communications between mobile nodes in the same service area. With all communications relayed through an access point, the basic service area corresponding to an infrastructure BSS is defined by the points in which transmissions from the access point can be received. For requirements exceeding the range limitations of an infrastructure BSS, IEEE 802.11 defines an extended service set (ESS) LAN by linking BSSs together by a backbone network. This type of configuration satisfies the needs of large coverage networks of arbitrary size and complexity. Examples of IBSS, infrastructure BSS and ESS networks are given in Fig. 2 [25,26].

The main enhancement of IEEE 802.11b was the standardization of a physical layer, able to support higher speeds of 5.5 and 11 Mbps. As IEEE 802.11 FHSS systems cannot support the higher speeds without violating current Federal Communications Committee (FCC) regulations, DSSS technique was selected as the exclusive physical layer technique. In this way, IEEE 802.11b is backwards compatible and can interoperate at 1 and 2 Mbps only with the 802.11 DSSS systems, and not with FHSS systems. To increase the data rate, 802.11b specifies an advanced coding technique called Complementary Code Keying (CCK). CCK consists of a set of 64 code words, 8-bit long, which can be distinguished by the receiver even in the presence of noise or interference. The CCK encodes 4 bits per carrier to achieve data rate 5.5 Mbps, and 8 bits per carrier to achieve 11 Mbps. Both speeds use Quadrature Phase Shift Keying (QPSK) modulation and 1.375 Mbps symbol rate. The IEEE 802.11b provides 11 Mbps in distances up to 300–400 m in open, outdoor environment and 30–50 m in indoor environment with low noise [23,25,26].

3. WEBNET AND WEBRJS-PIC

The WebNet is a small electronic device, capable of serving as a gateway between another electronic device and an ethernet network – for instance an intranet or the Internet. The user interface of the WebNet consists of a number of web pages contained in the device and presented by its built-in web server. A standard web browser is used to view and browse these pages [27].

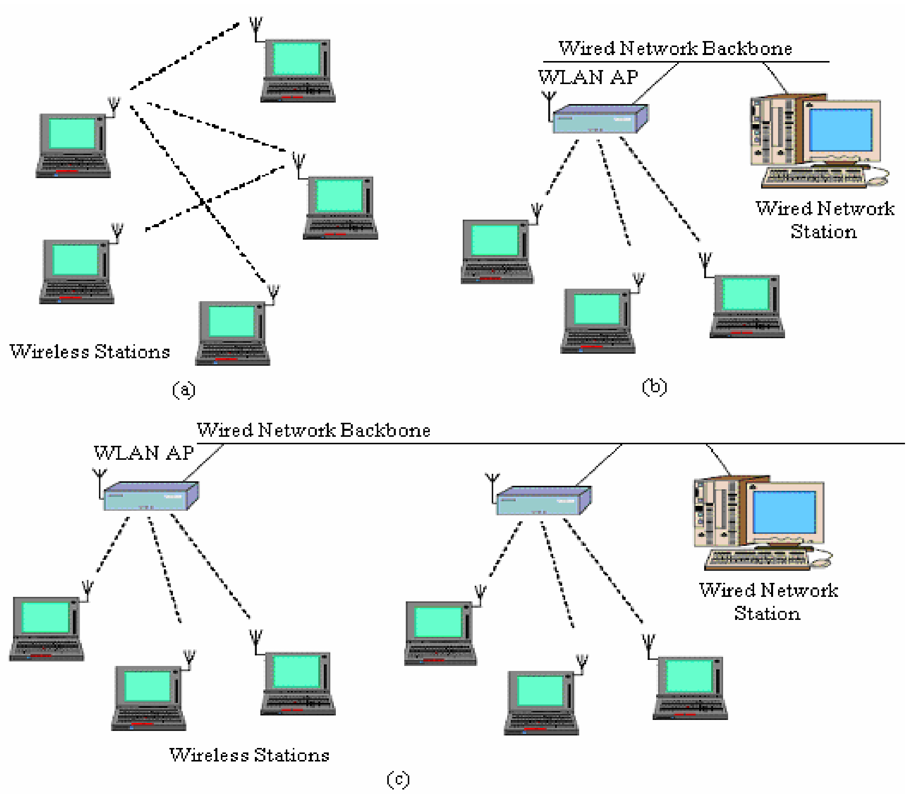

Figure 2. Types of IEEE 802.11 networks (a) Ad-Hoc mode (IBSS), (b) Infrastructure mode BSS, (c) Infrastructure mode ESS.

The WebNet is 6,7 cm x 4 cm sized DIMM module, which makes it suitable as an add-on module for another device. The IO186 WebNet module is a highly integrated internet interface module. It contains a complete Am80186ED CPU, 2 MB EDO DRAM, 2 MB FLASH memory and a 10 Mbps twisted pair ethernet interface (Fig. 3a). The module is packaged in a 144-pin 5V SO-DIMM [28,29]. For the benefit of this module a WebRJS-PIC adapter board is supplied. This board makes it possible to connect power, ethernet and RS-232 via standard sockets. Thus the WebRJS-PIC board can be considered motherboard for the WebNet, with the specialized purpose of providing RS-232 connectivity. The WebRJS-PIC adapter board contains an additional microcontroller, PIC16F876. The microcontroller opens possible connections to a wide range of different hardware interface types. All I/O ports of the microcontroller are accessible through a connector on the PCB [30].

WebNet is a single component, complete and compact Internet Gateway / Web-Server that allows add network connectivity to any electronic device. The SO-DIMM 144 module is easily integrated into existing or planned products bringing modern facilities to appliances. The flash based file system in the WebNet makes it easy, using FTP, to up- and download web pages, data files and application-specific programs. Featuring a scripting language WebNet can be programmed for any advanced application. Alternatively WebNet features a standard interface for an application processor, the flash based Microchip Inc. PIC-controllers, but any other processor can be used. With a standard web-browser as a user interface, user implements everything from simple static information, e.g. online manual pages, to dynamic configuration pages, active presentation pages and real-time surveillance of device (Fig.

3b) [29].

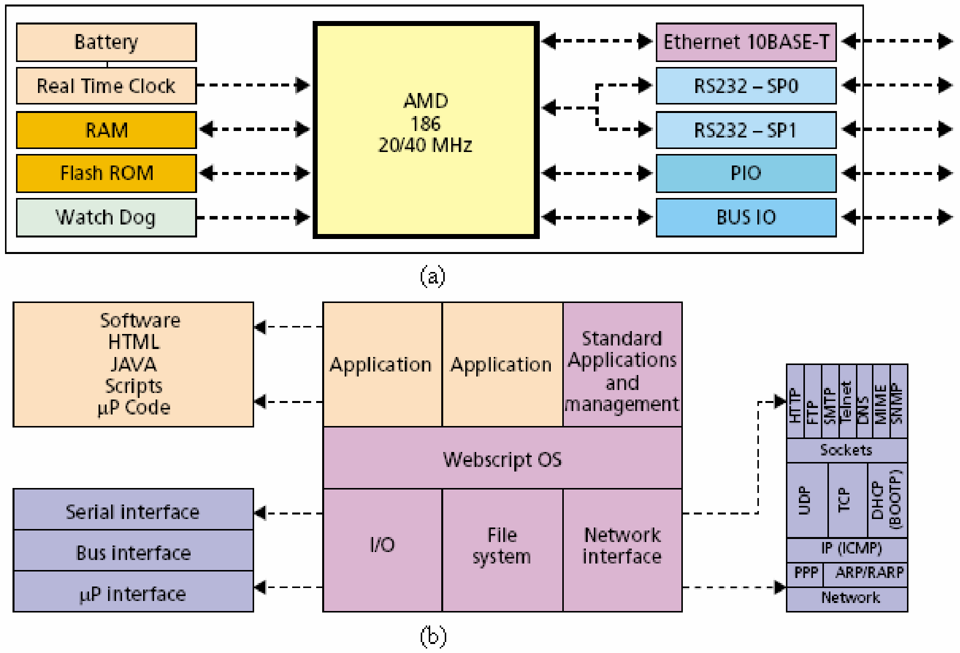

Figure 3. Block diagrams of WebNet (a) Hardware block diagram (b) Software block diagram.

The WebNet has an e-mail function allowing instant messages about the device to be sent to a user working on his/her PC, or on the user's mobile phone using SMS. The user could get warnings and status pictures for supervision purposes transferred over long distances, and would be able to monitor the system without being physically close to it. Using the Internet TCP/IP protocol, the system becomes broadly compatible. This makes it usable with clients on different platforms, such as DOS, UNIX, Windows etc., since browsers may be installed on PCs, Mac's or mainframes.There are numerous ways to design a WebNet software system.

The data from the device can be processed in different places and by code written in different languages as shown below [31,32]:

1. Data is processed on the device and the WebNet is merely a gateway to the processed data.
2. Data is processed on the WebNet using the built-in scripting language WebScript
3. Data is processed on the client PC, using e.g. Java code downloaded from the WebNet
4. Data is processed on the client PC using dedicated client software.

In our study, the software is implemented to control in device in Java. This software is downloaded automatically from the WebNet to the browser and executed by the browser.

The WebRJS-PIC board is part of the transmitter unit of our system. The purpose of WebRJS-PIC board is to provide running software of implementing common types of inputs and outputs to the WebNet. The WebRJS-PIC board includes a number of analog and digital input and output ports which may be used or modified to match the any application [30].

4. THE BIOTELEMETRY SYSTEM

In this study, oxygen saturation, blood pressure, heart rate and body temperature information of patients is transmitted to remote recipients via WLAN technology. Block diagram of the biotelemetry system is demonstrated in Fig. 4. This transmission realized almost zero transmission error owing to error check and correction algorithms in WLAN. For measuring of patients' oxygen saturation BIOPAC TSD123B transducer, for measuring of body temperature BIOPAC TSD202A transducer and for measurement blood pressure and heart rate Microlife BP 3AC1-1 measurement device is used (see Fig. 5).

The TSD123B transducer uses 660nm red and 940nm IR signals for optical transmission. Dimensions of this sterilizable transducer are 12 mm x 12 mm x 12 mm and weight is 6g . The TSD202A transducer, to be used for measuring of body temperature, has 1.7 mm diameter and 2 g in weight, measures temperature until 60°C with ±0, 2°C accurately [33]. For measuring blood pressure and heart rate Microlife BP 3AC1-1 measurement device is used without its display unit. Weight of this oscillometric device is 237 g except display unit, and it uses a capacitive sensor. Microlife BP 3AC1-1 measures blood pressure interval of 30 mmHg – 280 mmHg and heart rate interval of 40 Bpm – 200 Bpm. Accuracy of blood pressure and heart rate for this device are ±3mmHg and ±%5, respectively [34].

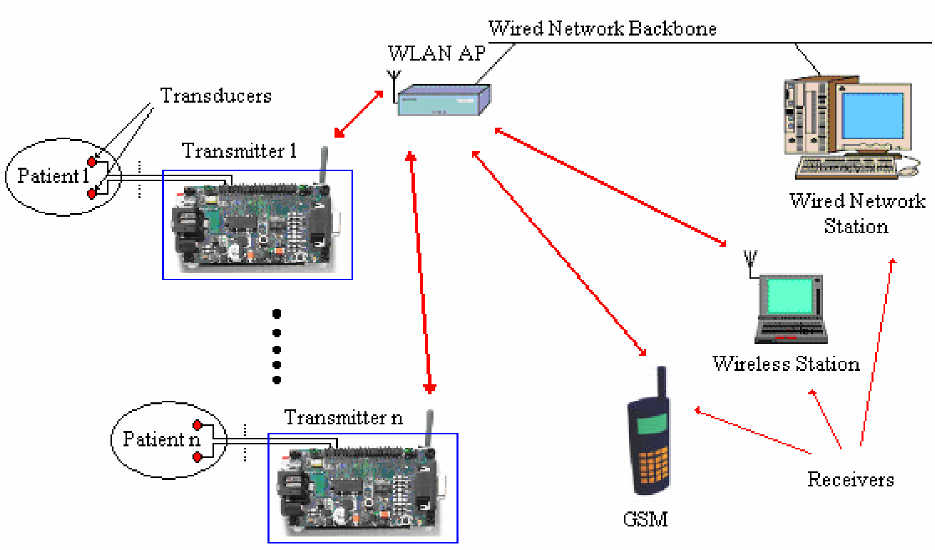

Figure 4. Block diagram of the biotelemetry system.

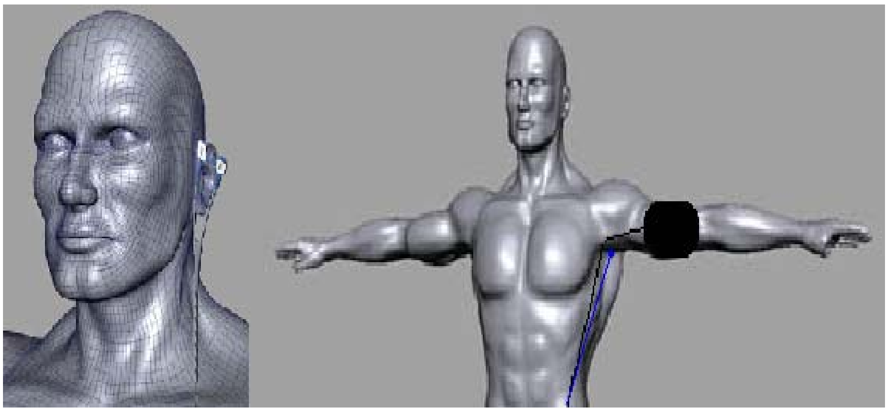

Figure 5. TSD123B transducer, Microlife BP 3AC1-1 cuff and TSD202A temperature transducer.

In this system, a dns server is used for connection from mobile receivers to mobile transmitters. For connection to patients, receivers need to connect to this dns server firstly. Mobil receivers are directed to a domain address like http://patientname.domainname by this upgradeable server. After connection and login, client sends a request to transmitter WebNet, and then a web page running internal web server on WebNet sends the request to the java script.

This script, whose algorithm has been given in Fig.6a, after doing initial definitions creates connections between WebRJS-PIC software and ethernet interface. After then, script converts html request to suitable form and sends to microcontroller software on the WebRJS-PIC. Then it waits request results and transmits them to the client.
Microcontroller software, which works on the WebRJS-PIC, reads data from transducers in every 6 minutes then processes them and saves to its registers. The microcontroller software creates connection with WebNet software after doing initial definitions, and waits command from it. Algorithm of the microcontroller software is shown in Fig. 6b. When suitable command delivers to the microcontroller, it sends the last 10 data to java script working on WebNet.

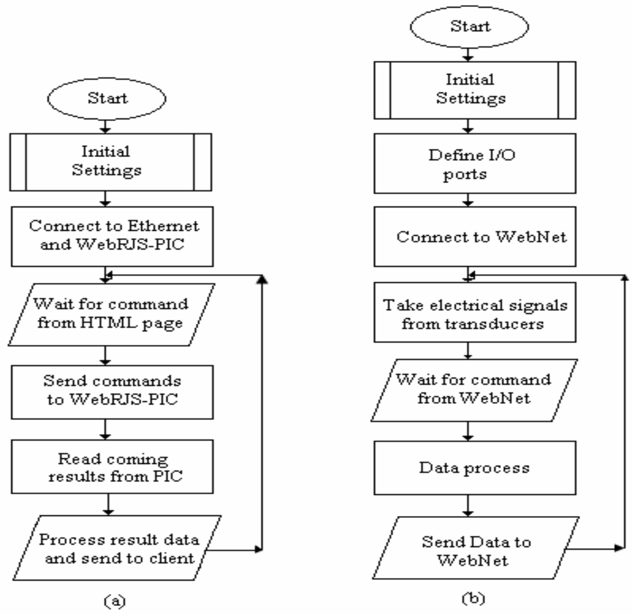

Figure 6. Algorithms of the system software (a)Algorithm of java script (b)Algorithm of microcontroller software.

Data communication between receiver and transmitter is realized by a web page. The screen out for a sample patient has been shown in Fig. 7. In this web page to be prepared with html tags and java scripts, is demonstrated personal information about the patient and measured values of the patient in last 1 hour with automatic scaling.

5. CONCLUSION

In this study, a biotelemetry system is developed using IEEE 802.11b WLAN, WebNet module and WebRJS-PIC adapter card. By realized system, some biological variables of a patient, who needs under medical observation, can be observed as wireless in any IEEE 802.11b wireless local area network. If our system is compared with the traditional systems, it has two major advantages. The first advantage is that faster data rate is provided in our system using IEEE 802.11b WLAN technology. While special transmitters which require special receivers used in traditional systems, the second advantage of our system, any TCP/IP supported device can be used in our system as system receiver. With developed system, both patients will be protected from infections in hospital and the patient will be feeling better psychologically. In addition, we expect that the number of free bed problems should be solved in hospitals. If we consider that wireless technologies is a candidate technology for use in centre of population in near future widely, both patients' and doctors' mobility will be provided with this system. The doctors will observe and diagnosis for a patient anywhere of the world.

With using this system for biotelemetric measurements, additional electromagnetic pollution will be prevented existing wireless system electromagnetic pollution. The system causes a little disturbance to the patient because of small dimensions. Also the system is low cost for hospitals and patients, too. Since transmission process is a developing technology day by day independently from the system, use of the system will be enlarged to an important ratio in a period of time. In addition, with increasing number of TCP/IP and Internet compatible device, it is thought that more practical solutions will be developed in receiver points.

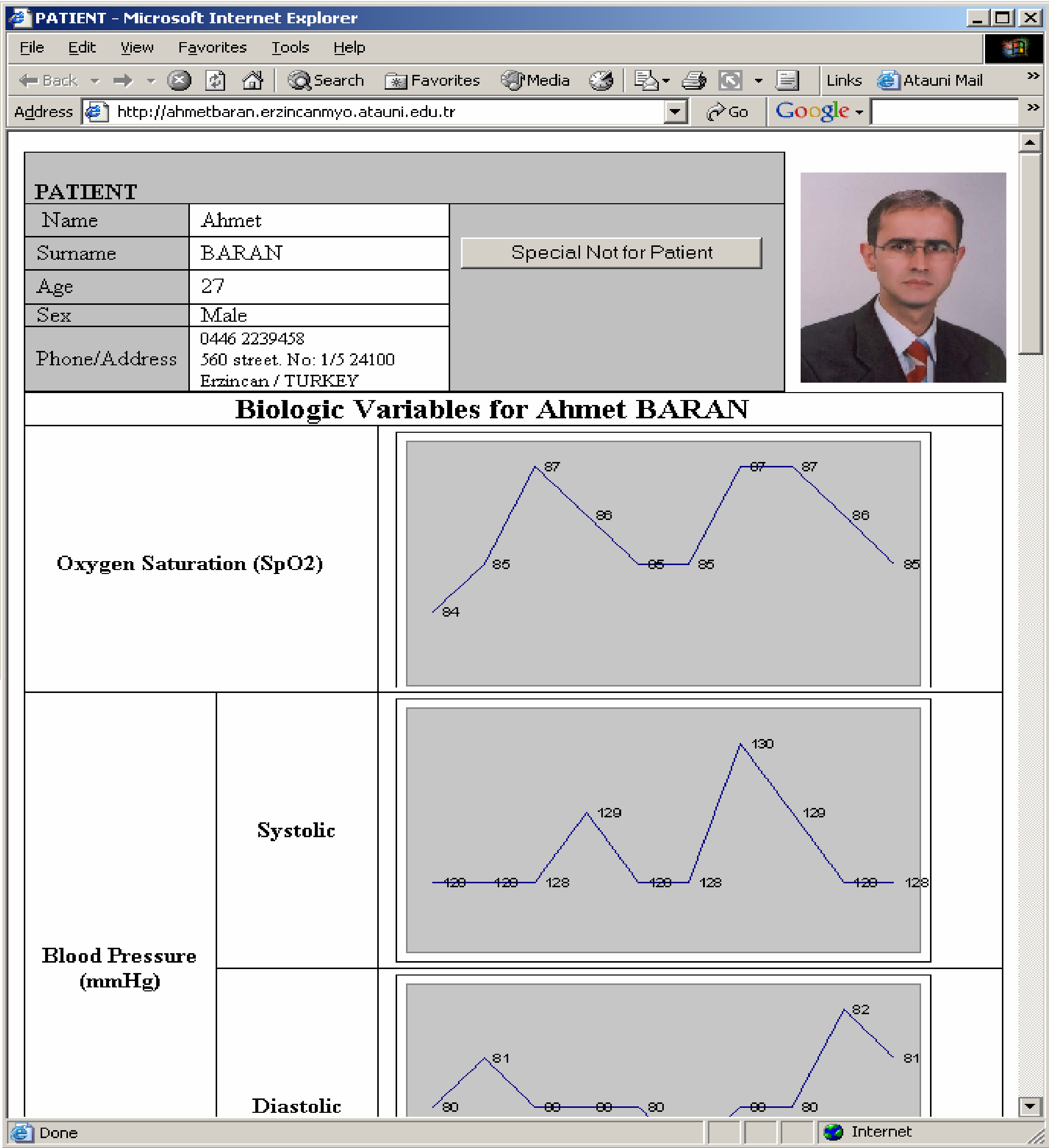

Figure 7. A sample web page screen out for a sample patient.

In spite of these advantages, there are some disadvantages and limits of the system. Causing electromagnetic pollution of the system is inevitable. It is thought that this electromagnetic pollution will give damage to environment. Effects of physical conditions like electric and magnetic fields, heat, humidity to the electronic parts of the system are other limits of the system. Furthermore, it is possible that viruses and hackers can give damage to software on transmitter.

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