AN EMBEDDED MOBILE HOME AUTOMATION SYSTEM

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Abstract: This paper proposes a home appliance automation system in design and realization. This system is accomplished by embedded boards, radio frequency (RF) transceivers, microprocessors, switching circuits, sensor circuits and GSM (Global System for Mobile Communication) modules. This system mainly consists of two subsystems for home appliance control and home security monitor. In the home appliance control, we combine RF and WAP (Wireless Application Protocol) technologies for controlling home appliances, where RF is for home network and WAP is for remote interconnect to home network via mobile communication. For all security concern or emergency occasion, a SMS (short message service) may automatically be generated from the microprocessor and sent to assigned cell phone number. The proposed system would not only offer personal mobility and life convenience, and also provide home security for better living environment.

1 INTRODUCTION

Home automation brings the distinct advancements of security, convenience and comfort for human life. Home appliances can be connected to outside world through network, no matter wireless or wired system is adopted. Control and monitor to home appliances remotely can be made from anywhere. The trends of home automation can be divided into two categories: one for home appliance control and energy management, while the other for household security and safety (Tan, 2002, Dewsbury, 2002). Home network would be combined with mobile network to realize dreams of intelligent home to mobile phone to control remotely home appliances (Nikolova, 2003). Home appliances will get smart in the future with incorporating some functions of sensor and control (Badami, 1998). Low power, low cost, short-range wireless circuit architectures are also equipped into those smart home appliances to achieve the always-connected home network (Tuttlebee, 2001). This is a novel originality to improve the life quality and to realize smart home.

Nikolova utilized mobile terminal to control home appliances (Nikolova, 2003). HAVI (Home Audio Video interoperability) was applied in home network, and WAP phone was remotely used to interconnect home network via mobile network. Tan also presented a similar architecture, using WAP phone to control home appliances (Tan, 2002). However, the Bluetooth wireless network technology was used in the house to replace wired connection to avoid disorderly household environment. By this concept, Chen combined Internet with Radio to implement home control system Chen, 2004) for more delicate control implementations.

Relative to use personal computer as home server, there is another choice for using embedded board. Ramakrishnan presented an embedded web server based on 16-bit microprocessor to implement web-based data acquisition and control (Ramakrishnan, 2004). Hartwig also presented a concept of wireless micro-server by integration of electronic devices (Hartwig, 2002). Some applications were studied for tele-health and patient monitoring at home for e-health applications. WAP-based telemedicine system to monitor the elderly persons in remote, or an Internet-based in-house control and monitoring system were interested in study. They combined home automation and healthcare system for an aging society Hung, 2003).

Home network technology is available in three main categories: Busline (Cebus, LonWorks, EIB, etc); Powerline (EIB Powerline, X10, etc) and Radio Frequency (WiFi-802.11, Bluetooth, Radio etc). Radio frequency is main difference from Busline and Powerline that no wires need to be connected to home appliances. Maybe only one chip is used to be ported to home appliances, and the intercommunication between home appliances would be implemented. A typical RF communication

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includes a pair of transceiver with encoding/decoding and modulation.

WAP is capable to show Internet contents on wireless clients, like mobile phones (Education, 2000) and enables to create web applications for mobile devices, based on Internet standards (HTML, XML and TCP/IP). WAP is also adopted as a boarder-free long distance communication and remote control.

While GSM of 900 MHz and 1800 MHz is used as voice communication channel frequencies in TDMA/FDMA (Jorg 2001, Gunnar, 1998), its stacked on GPRS can be used for always-on data communication (Jochim, 2001, Christoffer, 2001). GSM is mainly used for voice communication and short message service (SMS). In Taiwan and China, very high population of SMS is created. In this paper, GSM SMS will be adopted for emergency report to the user. The most difference between GSM and GPRS is that GPRS improves the wireless access to packet data network. So data transmission rates of GPRS are faster than GSM system. The always online feature is also an advantage for GPRS Christoffer 2001). GPRS in this paper is a means to transmit WAP message.

This paper proposes a feasible approach of home automation by integrating Radio connection and mobile communication. This system mainly consists of two subsystems: home appliance control system and emergency report system.

(1) Home appliance control system: A graphical user interface (GUI) is displayed on the WAP browser for our control operation while connecting through mobile communication (Gundavaram, 1996). Then, home users could remotely use WAP phone to control home appliance.
(2) Emergency report system: If some emergencies occur in the house such as a conflagration or temperature abnormality, the proposed emergency report system would automatically send SMS alerts to home users to prevent a disaster through GSM.

This system combines radio connection in our house with mobile communication around the world to offer personal mobility and convenience into our life. Moreover, it also provides security and prevents disaster for our house. System design, implementation and tests are presented.

2 THE PROPOSED HOME APPLIANCE SYSTEM

In this paper, an embedded home automation system is proposed. The proposed system architecture mainly consists of two subsystems in developing prototypes: (1) the home appliance control system; (2) emergency report system, are shown in Figures 1 and 2.

Home users could use WAP phone to control home appliance outside our house through the proposed home appliance control system. If any emergencies occur in the house such as a conflagration or temperature abnormality, the proposed emergency report system would automatically send SMS alerts to home users to prevent a disaster through GSM. It creates security for our house.

2.1 Home Appliance Control System

The home appliance control architecture is shown in Figure 3. The home user use mobile terminal (WAP phone) to connect to the embedded web server through wireless network. Then, a graphical user interface (GUI) displays on the WAP browser for our control operation. Choose a decided control to home appliances and push a button to transmit control information to the embedded server. After the embedded web server receives the control information from WAP phone, it would transform the control information to the mapping 4-bit control data. Then, the mapping 4-bit data would output to RF module in order to communication with home appliance controller. The home appliance controller analyzes the received 4-bit data to control corresponding home appliances. In the proposed system, home user could transmit control data from WAP phone to home appliance controller in order to switch home appliance. Similarly, the acknowledgement character could be transmitted from home appliance controller to WAP phone in order to response to home user that if this operation is success.

(a) The Embedded Web Server. The embedded web server is implemented using NET-Start!™ embedded board. The NET-Start!™ is a compact networking startup toolkit, based on a 32-bit ARM7TDMI network processor - S3C4510. The operating system called μClinux was ported to the embedded board by WISCORE Inc. The WAP phone can connect to the embedded web server through wireless network. In addition, we add extra RF transceiver module to this embedded board in order to communication with home appliance controller in our house. In fact, we use this embedded board to play as communication interface from WAP phone to home appliance controller.

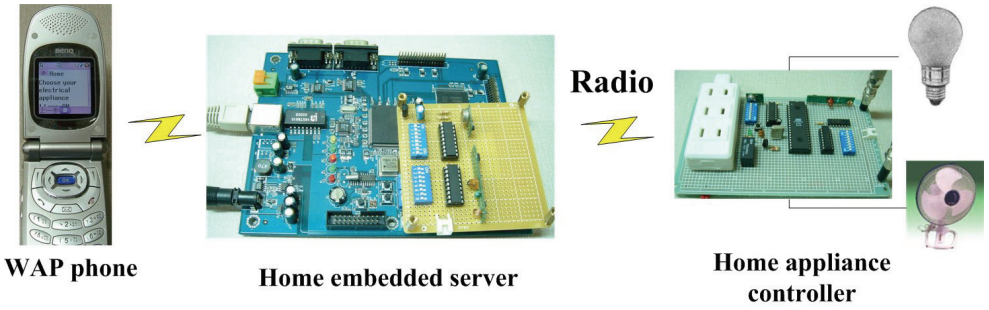


Figure 1: Concept of the proposed home appliance control.

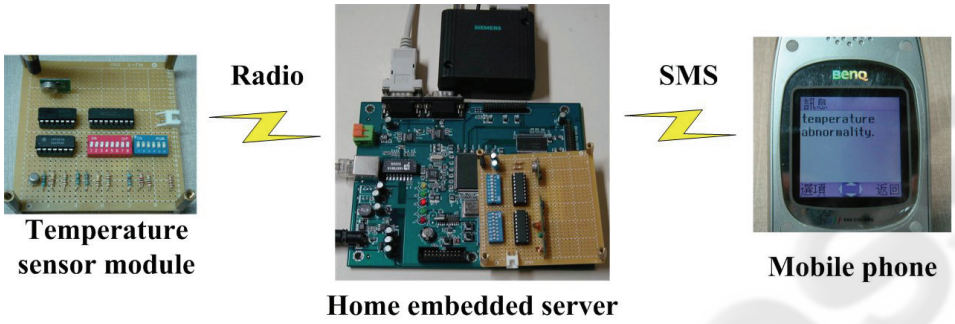


Figure 2: Concept of the emergency report.

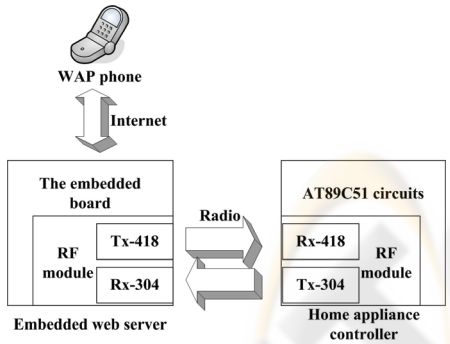


Figure 3: The proposed home appliance control.

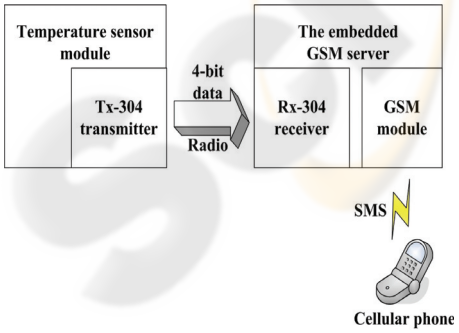


Figure 4: The proposed emergency report.

(b) Home Appliance Controller. The home appliance controller consists of an AT89C51 microprocessor, a RF transceiver module and a switching circuit. We choose AT89C51 to handle communication and to give the command of switching circuit to turn on/off home appliances. The home appliance controller receives 4-bit control data from the embedded web server through radio by using RF module. Then, AT89C51 would drive switching circuit to control the home appliance, which home users want to control, by gauging this received 4-bit data.

2.2 The Emergency Report System

The architecture of the proposed emergency report system is depicted in Figure 4. If temperature is higher than normal value inside our house, temperature sensor module would transmit 4-bit data to the embedded server through radio by using Tx-304 transmitter. When the embedded server receives 4-bits data, it would send SMS to home user by writing AT commands to GSM module. The emergency report system provides security and prevents disaster for our house. The proposed emergency report system consists of temperature sensor module and the embedded server.

(a) Temperature Sensor Module. The AD590 is a

two-terminal integrated circuit temperature transducer that produces an output current proportion to absolute temperature. The output current of sensor AD-590 would be converted to voltage by passing a 5K precision resistor. The AD-590 is used in sensor module to detect temperature for home security.

(b) The Embedded GSM Server. The embedded GSM server consists of a RX-304 receiver, the embedded board and a GSM module. The Rx-304 receiver could be connected with temperature sensor module through radio. Then, the embedded GSM server would send message to home user's cellular phone through GSM on the occurrence of the disaster.

(c) 4-bit Data Corresponding Table. In proposed home appliance control system, we transmit 4-bit data to control home appliances through radio by using RF module. In proposed emergency report system, we send message to home user according to 4 bit data transmitted from sensor module to the embedded server. The 4-bit data are assigned to each different mode of control.

2.3 The Circuit of RF Module

We transmit 4-bit control data through radio using RF module as the wireless environment in house. The RF module, includes a Tx-418 transmitter and an Rx-304 receiver, as shown in Fig. 5, is added to the embedded broad in order to communicate with home appliance controller inside our house. Frequency 418 is assigned to send from the embedded server to the home appliance controller, and vise versa for frequency 304. The RF module is applied as the wireless interface in the proposed system.

(a) Tx-304 Transmitter. The transmitter of RF module includes a DIP switch, a encode IC HT-12E and a transmitting circuit as shown in Figure 4. For HT-12E, A1 to A8 are its address codes that have 8-bit. We can use dip switch or microprocessor to set it up. D1 to D4 are data inputs of 4-bit. When we want to transmit data, we must set an address code with data together. The receiver can get data when the address code of transmitter and that of receiver are matched.

(b) Rx-304 Receiver. The receiver of RF module includes a DIP switch, a decode IC HT-12D and a receiving circuit as shown in Figure 5. A1 to A8 is the address codes of HT-12D that are compared with the address codes of HT-12E. It will check three times repeatedly. If it is correct, 4-bit data would be received through Rx-304 receiver.

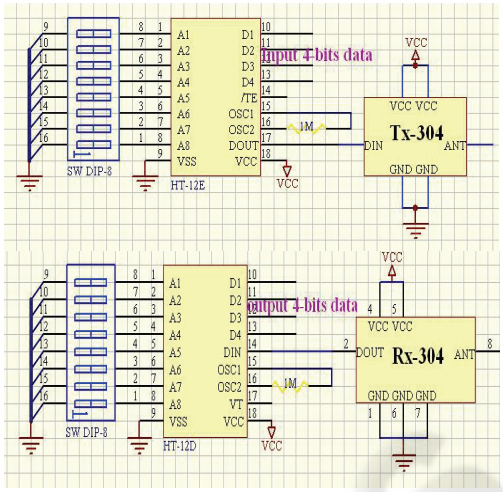


Figure 5: Tx-304/RX-304 transceiver.

2.4 Home Appliance Control Application Software

The software interaction for home appliance control system is depicted in Figure 6. It includes several programs that are composed of WML program, the embedded web server software suite, CGI program and 8051 control program.

(1) The NET-Start!^{TM} embedded board is used to be as a embedded context server using the micro-server program thttpd.

(2) Develop web page written in WML and CGI program written in C language. Place them in the embedded context server in order to be accessed from mobile terminal.

(3) Utilize WAP phone as mobile terminal to access web page to be displayed on the WAP browser. The web page is designed for home user to choose home appliance to control.

(4) The CGI program is used to form an acknowledgment web page to user on the WAP browser and to transmit control data to activate home appliance controller through radio.

(5) When receiving the control data, 8051 control program would turn the home appliance on/off. At the same time, 8051 control program also give an acknowledge response to embedded server.

(6) We can choose appropriate appliance via the software interaction.

(a) Web Page on WAP Browser Simulator. We develop web page on WAP browser simulator using WML language in order to control

appliance remotely. We can download the Nokia mobile internet toolkit (NMIT) to develop our web page from Website http://forum.nokia.com. We develop and edit mobile-browsing content by using NMIT by Nokia. Then, we preview WML language and display it on simulate WAP phone, as shown in Figure 8. The detail specifications can be downloaded for NMIT user guide from Nokia website.

(b) CGI Programming. CGI is common gateway interface. The CGI standard was developed jointly by CERN (the European Laboratory for Particle Physics) and NCSA (the National Center for Supercomputing Applications). The CGI standard provides a consistent interface between Web server and application programs that strong their capability. In other words, the Web server can call up a program through CGI, while passing user-specific data to the program. CGI is not a programming language or a protocol. CGI is only an interface that enables software to communication (Gundavaram, 1996). The CGI program can be written by using C, Perl or Shell script. In our paper, use C language to implement the CGI program. The user gives particular requests (information) from the WWW browser to Web server. The Web server shares this information with the CGI program. This information is delivered by using environment variables. When the CGI program is implemented, we place the CGI program in legal CGI path. Thus, we can deliver data requested from WAP browser to the CGI program through common gateway interface. In our work, the CGI program is used to do two things. First, the CGI program can output control signal to control home appliance through radio. Second, the CGI program responses a new document to user in order to check if action is success.

(C) Home Appliance Control Program. In the program, we initialize some settings and wait for a negative edge-trigger of VT to enter interrupt sub-program. We receive 4-bit data from embedded server through radio. Then we judge 4-bit data to turn on/off the corresponding home appliance. If the action is success, we would response 4-bit data to server to be as acknowledgement code.

2.5 Emergency Report System Application

The software interaction of emergency report system includes a serial program to activate GSM module connected to embedded board via RS-232, as shown in Figure 7. While sensor module is activated due to a disaster such as a conflagration or temperature abnormality, SMS alerts would be sent to user's cellular phone by running serial program. Then, this alert would be displayed on the cellular phone to give home user a warning. Serial program edited by c language is installed to communicate with GSM module. First, we have to initial settings for opening RS-232 port. Then, we activate GSM module by writing AT command. Finally, we can send short message to mobile phone using GSM module.

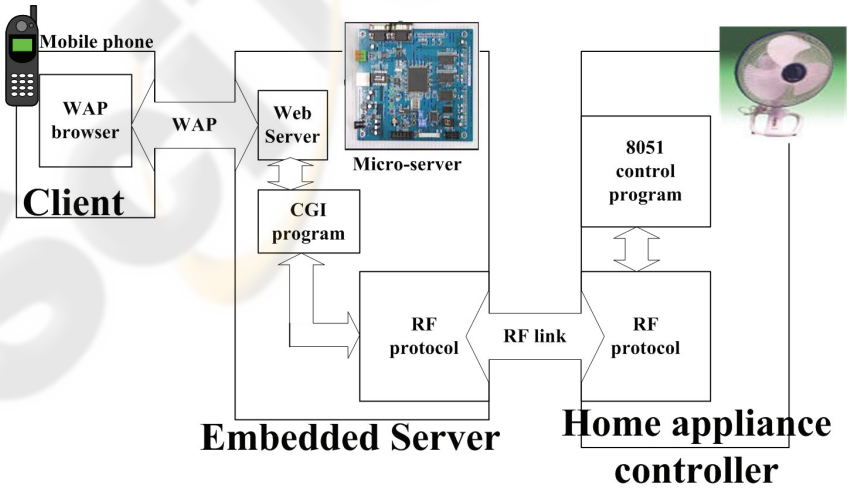


Figure 6: Control interaction.

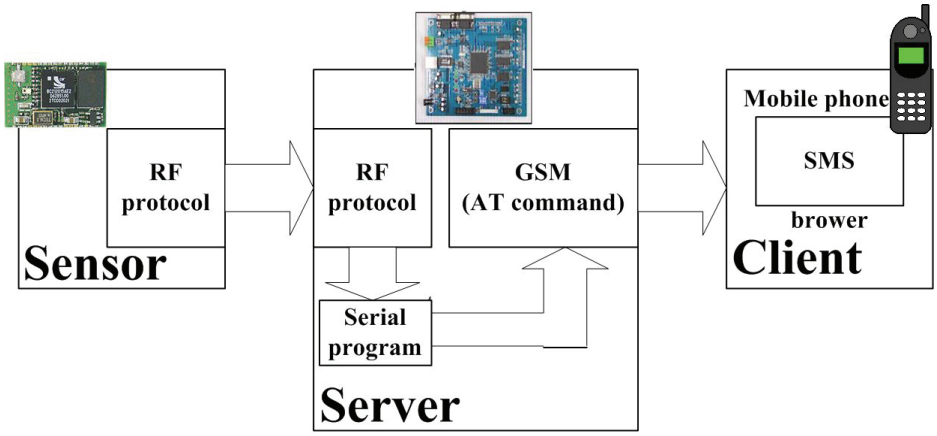


Figure 7: Emergency report interaction.

3 IMPLEMENTATION AND TEST

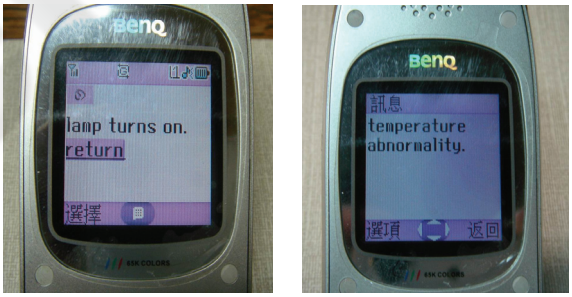
The proposed embedded home appliance control and security system design is presented. The system hardware has been implemented on an embedded board and microprocessor linking via RF modules for two general functions of home appliance control application and emergency report application. System software interacts with hardware in an integration performance for verification and tests.

3.1 Home Appliance Control

With home appliance control architecture, home user can use mobile terminal (WAP phone) to control home appliances, such as lamp shown in Figure 8, or other home appliances. It refers to system architecture as shown by Figure 3 and Figure 6. After this operation is success, acknowledge character by graphical user interface (GUI) is displayed on the WAP browser for our control operation, as shown in Figure 9(a). Acknowledgement is a necessary characteristic to ensure a successful operation.

(a) (b)

Figure 8: Lamp control.



(a) (b)

Figure 9: SMS emergency report.

3.2 Emergency Report System

While an abnormal condition occurs at home appliance, an emergency report will be sent to the home user by SMS alerts through GSM as shown in Figure 9(b), referring to Figure 4 and Figure 7 for operation. Sensors where are necessary should be installed for monitoring. The received SMS alerts would be displayed on user's mobile phone as a

warning to home user.

4 CONCLUSION

The proposed system is designed and realized successfully with full function tests. The system can not only control remotely home appliance but also protect home security. The proposed system provides a network-based approach to make it possible by combining RF and mobile communication, that personal mobility is very much appreciated. It has been verified to offer personal mobility and security into domestic life, and to fulfill the ideal home automation system into real world. Modern and developed countries, people might need to work for 9-5, their home situation might be a significant concern to most people. Home automation as well as security awareness may offer a fulfillment to those expectations in highly mobility performance. In this paper, we present a feasible solution of home automation by integrating the Internet, RF communication and mobile communication into an operational system. The proposed system can not only be a part of home appliance remote control system using WAP phone, but also be a part of home security report system for household emergency to the users through SMS on cell phone. The performance has been verified in good condition to match the design requirements.

Based on the proposed system, the main objectives have been achieved as summarized. (1) The proposed system provides the network-based solution of the network accessibility and network acquisition. (2) It combines RF home network with mobile communication to offer personal mobility and convenience for home users. (3) RF home network technology is used to replace traditional wired connection to avoid disorderly household environment or wasting space. (4) The embedded board is used to replace traditional personal computer to be as a home server for saving household space. (5) This system improves the home security of household environment due to the emergency report mechanism. (6) The overall system performance increases the residence quality, comfort and convenience of home life.

In this paper, some shortages and problems should be mentioned. (1) The time of establishing a connection to the server requires about 7 to 9 seconds, and after connecting to the server, the time required for dynamic generation of WML is about 1 to 3 seconds in average. This problem might be improved 3G (third-generation) or B3G (beyond 3G) system. The emerging 3G or B3G mobile communication would promote a much higher data rate, and newer versions of WAP specifications would promote stability. (2) EMI (Electromagnetic Interference) presents a serious influence on RF transceiver module that devalues the effective distance and its stability. Higher frequency RF module or message protocol may improve this problem. New wireless technologies, such as Bluetooth or WiFi-802.11, could be applied. The advantages of these emerging technologies are higher data rates, longer transmitting distance and excellent stability. It should be a feasible solution by integrating emerging wireless technologies into home automation in the future.

REFERENCES

Badami, V. V., Chbat, N. W., 1998, “Home Appliances Get Smart”, IEEE Spectrum, Vol. 35, No. 8, pp. 36-43, Aug. 1998.

Chen, J., Kuan, J. T., 2004, “A Remote Control System for Home Appliances using the Internet and Radio Connection”, IEEE International Symposium on Computer Aided Control Systems Design, pp.249-254, Sept. 2004.

Dewsbury, D., Clarke, K., 2002, “Appropriate Home Technology: Depending on Dependable Technology Systems”, Proceedings of the ENHR Conference, July 2002.

Hartwig, S., Resch, P., 2002, “Wireless Microservers”, Pervasive Computing, IEEE, Volume 1, Issue 2, pp. 58-66, April-June 2002.

Hung, K., Zhang, Y. T., 2003, “Implementation of a WAP-based Telemedicine System for Patient Monitoring”, IEEE Transactions on Information Technology in Biomedicine, Volume 7, Issue 2, pp. 101-107, June 2003.

Nikolova, M., Meijs, F., 2003, “Remote Mobile Control of Home Appliances”, IEEE Transactions on Consumer Electronics, Vol. 49, No. 1, pp. 123-127, Feb. 2003.

Ramakrishnan, A., 2004, “16-bit Embedded Web Server”, Sensors for Industry Conference, Proceedings the ISA/IEEE, pp. 187-193, 2004.

Tan, K. K., Soh, C. Y., 2002, “Internet Home Control System using Bluetooth over WAP”, Engineering Science and Education Journal, Vol. 11, No. 4, pp. 126-132, Aug. 2002.

Tan, K. K., Soh, C. Y., Wang, K. N., 2002, “Development of an Internet Home Control System”, Proceedings of the 2002 Int’l Conference on Computer Aided Control Systems Design, Volume 2, pp. 1120-1125, Sept. 2002.

Tuttlebe**e,** W., 2001, “Wireless in the Home**”,** Electronics & Communication Engineering Journal, Vol. 13, No. 5, pp. 194-194, Oct. 2001.

Gundavaram, S., 1996, CGI programming on the World Wide Web, O'Reilly & Associates, Inc., 1996.
Education, B. V., 2000, Mobile Networking with WAP, Vieweg.
Jorg, E., 2001, GSM Switching, Services and Protocols, John Wiley & Sons.
Gunnar, H., 1998, GSM Networks: Protocols, Terminology and Implementation, Artech House Publishers.
Joachim, T., 2001, The GSM Network: GPRS Evolution: One Step toward UMTS, John Wiley & Sons.
Christoffer, A., 2001, GPRS and 3G Wireless Applications, John Wiley & Sons.
Carr, J. J., 1993, Sensors and Circuits, PTR prentice-Hall.