Using Wireless Interfaces in a Smart Home Model

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Abstract – **In this paper the application of wireless interfaces in embedded systems for monitoring and control is examined. A model of smart house is synthesized, applying wireless interfaces, designed for educational purposes. The core of the system is Arduino board with a possibility of remote Android based control.**

Keywords – **Embedded Systems, Wireless Interfaces, Smart Home Model, Arduino.**

I. Introduction

The architecture and the features of embedded systems develop continuously - they are becoming more diverse in composition and functions, more flexible, adaptable and reliable.

Their development through the years can be summarized to the following three phases:

- In the early days of occurrence and development of the microprocessor systems they are single- or multiple-board systems, based on microprocessors, memories and peripheral units - timers, parallel, synchronous and asynchronous serial interfaces, etc. as separate ICs.
- The occurence of microcontrollers in the early 70s of the last century leads to increased reliability, speed, flexibility, miniaturization.
- Nowadays, together with the growing variety of microcontrollers with enhanced features and parameters, on one hand the number and type of the peripheral intelligent programmable devices grows increasingly - sensor units, actuators, etc., and on the other control is not limited only to the use of microcontrollers as control devices.

Wireless interfaces allow building networks consisting of heterogeneous in nature components. In the process of controlling the intelligent programmable modules, collection and processing of information from them and other activities, easily can be incorporated a variety of "standard" mobile devices such as smartphones, tablets, laptops and more.

In general the methods and tools for monitoring, control, collection and processing of data using wireless interfaces evolve rapidly and are used in all spheres of life: building automation, industrial applications, automotive and medical industry and many others.

Wireless communication offers a flexible and reliable approach to object control, obtaining information on its parameters and state, receiving data and organize them in a database, etc.

There are various forms of wireless communication based on different frequency bands, modulation methods and protocols, which are briefly presented in Part II.

A smart home model implementing wireless interfaces is presented in part III.

The model is intended for educational purposes in Microprocessor Circuits and Embedded Systems for the Bachelor degree students in Electronics in the Technical University of Gabrovo.

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II. A Short Survey on Wireless Interfaces

As wireless interfaces provide a range of advantages in data transfer in modern embedded systems, more and more devices that have the ability to connect wirelessly with others are produced. That is why the terms "Internet of Things" and "Wireless Connectivity of Things" are presently widely spread. [1], [2], [3], [4]

Using the infrared range for data transfer is implemented long ago, for instance as a remote control of various devices. But due to a number of advantages it gained a rapid development and is widely used to connect various devices such as PC and peripherals.

Advantages:

- Infrared signals are easily generated and identified;
- As the generated signals are out of the limits of the visible spectrum, it is easy to apply optical filters, excluding totally the visible light and therefore the interference;
- High level of channel safety;
- Low price of the hardware and also lack of law regulation.

Drawbacks:

- Need of direct visibility and therefore ability for short distance connection. That limits its application in implementing larger networks;
- The data transfer is peer to peer.

Bluetooth interface is especially made to replace the cable connections at office and home appliances. Frequencies in the 2,4 - 5 GHz range are used, a frequency band initially reserved for industrial scientific and medical (ISM) purposes. Nowadays it is widely used for data transfer in local wireless networks. The Bluetooth specification is maintained by Bluetooth Special Interest Group (SIG), founded in 1998.

Main features:

- Low power radio connection – typical power consumed about 1 mW;
- Typical range – 10 m;
- Data baud rate, initially 1 Mb/s, bu for instance Bluetooth 2.0 - to 3 Mb/s at distances to 100 m;
- Simultaneous connection with up to 8 devices.

The advantages of the Bluetooth technology are reduced size of the equipment, simple usage, safety of the data transferred, and good maintenance of the standard.

Some disadvantages are the comparatively high power consumption and impossibility to organize complex configuration networks.

Unlike other wireless technologies, where the aim is to provide high data transfer rate, long distances, etc., *ZigBee* (IEEE 802.15.4) [3] is created with opposite requirements for small range, low price, low power consumption, low data transfer range and low size of the equipment used, and also low requirements to the software. It uses the standard „Low-Rate Wireless Personal Area Networks - LR-WPAN - IEEE 802.15.4". Like Bluetooth, the radio band ISM is used.

It is suitable especially for home automation systems and some measurement and control systems together with using not expensive microcontrollers. The data transfer rate is comparatively low and the power consumption - minimal. Main application areas are as follows: receiving data from moving or rotating parts of conveyers, robots, etc., industrial systems for monitoring and control, wireless connection with sensors, tracing the route of the movement and location of property and equipment, security systems, etc.

The ZigBee standard, like Bluetooth, uses the baud transfer range of 2,4 GHz. The largest baud rate is 250 kbit/s. Although it provides typical data transfer distance 10 m, there are no requirements to the transmitter power. The most common transmitters are 1 mW (to 10 m), 10 mW for distance to 80 m indoors and to 1 km at line of sight. Increasing the distance can be achieved using antennas with a special design.

Minimized power consumed is a result of the fact that the slave devices are in idle state most of the time. They get active for short periods of time only to confirm their presence in the network.

Implementing ZigBee networks with various topologies could be configured – star, tree, mesh.

Connecting the components of an embedded system to Internet, including via Wi-Fi, results in additional advantages as the user can access the network components almost from everywhere [5]. Furthermore no special knowledge and skills are required to configure the network.

The main advantages of the Wi-Fi are the following:

- No licensed radio range is used and no law regulation for individual users;
- Quickly developing area, which allows usage of more and more devices communicating via such interfaces;
- Relatively low price;
- Roaming is possible, which allows the user with mobile devices to move from one access point to another;
- There are different levels of data encryption to protect traffic, etc.

A brief comparison of wireless interfaces for embedded systems according to different criteria is given in Table 1 and Table 2 [1], [3].

TABLE I

	Wi-Fi	Bluetooth	Bluetooth LE	ZigBee	Sub GHz
Internet-Connected Device	Best	OK	OK	Poor	Poor
Smartphone Accessory	OK	Best	OK	Poor	Poor
Range	OK	OK	OK	OK	Best
Low Power Consumption	OK	OK	Best	OK	Best
High Data Rate	Best	OK	Poor	Poor	Poor
Interoperability Between Vendors	Best	Best	OK	Poor	Poor

III. THE SMART HOME MODEL

The smart home model is a suitable complex example to study various components of embedded systems - control devices and actuators, sensor modules, interfaces for data exchange and in particular the interface "man-machine". It also provides wide opportunities for implementation and testing of a number of modern wireless interfaces.

An example of such a system is shown in Fig. 1 [6].

Fig. 1. A smart home example

The main criteria, defining a building as "smart", are the following [6]:

- Input system, which receives information through a corresponding receiver. This can be done in four ways: by sensors (in real time), internally stored and recovered data, manually entered (programming and reprogramming) by the users and available online (Internet).
- Processing and analysis of information - performed by control system;
- Output system which responds to input data in the form of some actions;
- Response time requirements;
- Self-teaching ability.

The following stages can be identified in the development and services of the smart home:

1. First stage – the components are autonomous devices which communicate with other devices in home. These first devices are: bought and installed (and a part of) a home security system; a home cinema system or Do It Yourself (DIY). Using a variety of communication technologies, they usually do not communicate with each other directly but with their controllers.

TABLE II. A COMPARISON OF THREE LEADING WIRELESS TECHNOLOGIES

Parameter, m	Bluetooth/IEEE 802.15.1	ZigBee/ IEEE 802.15.4	Wi-Fi/ IEEE 802.11
Distance, m	~ 10 (50-100)	10	~100
Baud rate, Mbit/s	0.723	0.250	1-2 to 54
Max number of devices in the network	8	245	unlimited
Power consumption, mW	10	1	50
Operational time supplied with 2 baterries AA	-	6 months in standby mode	-
Price/complexity, conditioned units	10	1	20
Main purpose	A connection PC - peripheral devices	Wireless sensor networks	Wireless Ethernet extention

2. The second stage is the Internet connectivity - once connected with Internet the devices could be controlled via a smartphone or other mobile devices.

3. In the third stage these smart devices can communicate and exchange information between each other, without necessity of a human intervention. [7]

The wireless interfaces begin to be widely applied during the second and third stage.

The architecture of the smart home model is shown in Fig. 2.

For now the following functions have been implemented:

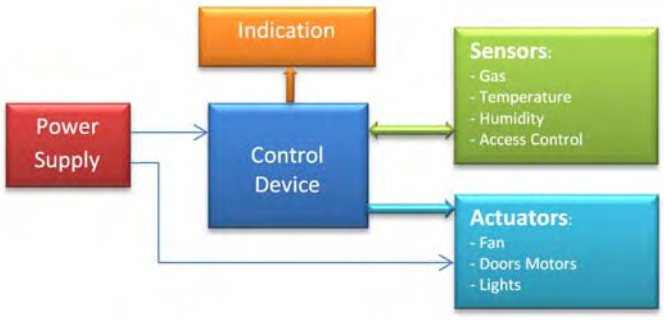

Fig. 2. The architecture of the smart home model

- Access control with Radio Frequency Identification (RFID);
- A garage door control via Bluetooth interface;
- A smoke senor;
- Detecting of presence and turn on / off lights;
- Measurement, indicating and regulating the environment temperature;
- Humidity measurement and indicating;
- Remote control of indoor devices via Bluetooth interface
- LCD indication.

The model components - the control unit and the sensors and actuators have been selected taking into account the compromise between low cost and desired features, because it is intended for educational purposes [8].

The open hardware development board Arduino Uno is chosen as a control unit (Fig. 3) [9]. It is suitable because of its compact size and low cost. It is based on the 8-bit RISC Atmel microcontroller – ATMega328. The microcontroller includes 32 KB Flash program memory, 2 KB SRAM data memory, 2 8-bit and 1 16-bit timer/counter, RTC, 8-channel 10-bit ADC, serial interfaces (USART, SPI, IIC), etc.

Arduino is a good choice for educational and hobby purposes, as it can be used as a ready to use core for an embedded system:

- A possibility is provided to power supply and program the microcontroller and peripherals via USB from a PC, and also independently - from a separate connectors for power supply and in-circuit serial programming;
- Clock frequency;
- Reset circuit;
- Expansion connectors accessing all the general purpose input/output pins of the microcontroller. It is possible easily to connect various peripheral modules to them and also to put on the Arduino board and connect so called shields with various purpose produced by many companies.

In future improvements including web-based control Arduino Uno could be used with an Ethernet shield or to be easily changed with another compatible development board, for instance Arduino Leonardo.

The access control is implemented using radio-frequency identification (RFID) module, which is intended for access control, personal identification, home automation, etc. A mini-RFID module has been chosen, with 125 kHz frequency, distance for reading to 35 mm. It is used for reading passive RFID tags, cards, etc.

For the remote control of devices such as garage door, lights, etc. bluetooth interface is implemented by the inexpensive module HC-05. Some features: 2.4GHz ISM band, supports baud rates 2400 -1382400, default COM setting: 9600, N, 8,1.

The doors of the room and the garage are closed/opened by small motors.

Mini PIR sensor HC-SR505 is implemented *to detect motion* for distance to 3 m, induction angle: <100 degree cone angle and induction distance - 3 meters.

Temperature and humidity are measured by sensor module DHT-22 with accuracy: humidity +-2%RH (max +-5%RH); temperature <+-0,5 Celsius; resolution: humidity 0.1%RH; temperature 0.1 Celsius.

With increasing/ decreasing the temperature a fan is switched on/ off and also its speed changes when changing the temperature range.

The sensor MQ-2 module is useful for detecting gas leakage - LPG, i-butane, propane, methane, alcohol, hydrogen and smoke for home and industrial applications.

Fig. 3. Arduino Uno Development board

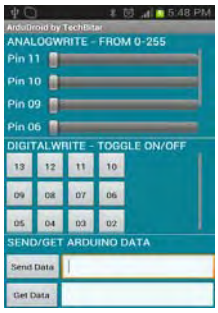

Fig. 4. Ardudroid application

To remotely control some devices via bluetooth interface and Android based device, like tablet, smartphone, etc., the free application Ardudroid is used (Fig. 4) [10]. It allows a direct control of the development board pins - digital, analog and serial interface.

IV. Conclusion

The implementation of wireless interfaces in embedded systems for various applications is presented.

A Smart Home model is designed. It is used in teaching "Microprocessor Circuits" and „Embedded Systems" for the Bachelor degree students in Electronics in the Technical University of Gabrovo. The model can be used to study the various components of embedded systems, in particular the wireless interfaces. It is convinient because, unlike other hardware development tools used in the laboratory classes, it includes several devices interfacing wireless in one project.

The further development of the project includes remote monitoring and control via web-based interface (Ethernet and Wi-Fi), and the development of additional modules to the system.

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