A Short Survey on Wireless Interfaces in Embedded Systems

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Abstract – **A short survey on the main features and parameters of wireless interfaces is presented in the present paper in relation to their application in the modern embedded systems. They are more and more widely used to connect the increasing number of "intelligent", programmable peripherals - sensors, actuators, etc., allowing not only reducing the number of the wires, but also distance monitoring and control of the object.**

Keywords – **Wireless Interfaces, Embedded Systems.**

I. Introduction

The embedded microprocessor systems are widely spread long ago almost in all the areas of our life - industry, home, office, automobiles, public activities, etc. This leads to continuous and rapid improvement of their features, such as reliability, flexibility, security, adaptability, cost, dimensions, etc.

Along with the control devices - microcontrollers, having a wide variety of building blocks and improved features, the peripherals (sensors, actuators, etc.) quickly evolve too, becoming more "intelligent". This coupled with the fact that embedded systems are sometimes used in extreme ambient conditions - electromagnetic interference, temperature variations, humidity, dust, vibration, etc., leads to the need of improving the means of communication: between the man and the embedded system; between the components of the embedded system (Fig. 1); in a network of embedded systems. As an example we could take the development of user interface in embedded systems over the years - beginning with buttons, keyboard, seven-segment indication, LCD, to the possible and comfortable use of modern touchscreen devices, such as widely spread personal mobile devices - smartphones, tablets, etc.

The increasing number of programmable devices in embedded systems supposes rapid development of wireless interfaces in order to avoid cable connections. There is a large variety of them depending on the embedded systems application areas [1], [2]. Presently they are mostly used at smart home applications, access control, smart sensor networks, remote industrial monitoring and control, etc. in the Machine-to-Machine and Man-Machine interaction, and sensor connections.

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The present paper examines some of the most common modern wireless interfaces in the areas of home automation and Internet-of-Things (IoT) in relation to study cases in Microprocessor Circuits and Embedded Systems for the Bachelor degree students in Electronics at the Technical University of Gabrovo.

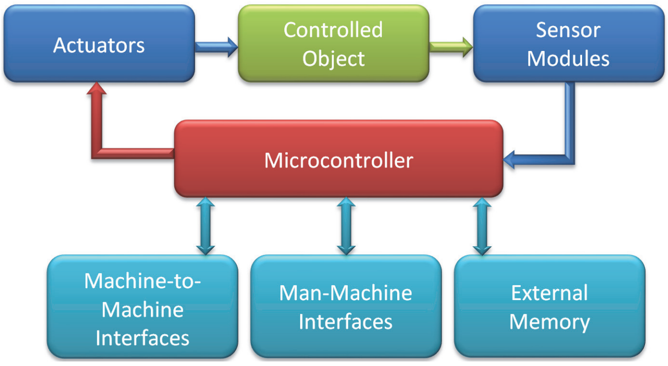

Fig. 1. Hypothetic block diagram of an embedded system

II. A Short Survey on Wireless Interfaces for Embedded Systems Applications

Infrared Data Association (IrDA)

IrDA is an optical open channel interface, allowing peer-to-peer communication in short distances. The baud rate is 2,4 kbps - 1 Gbps in 1 m distance according to several specifications defining six ranges with different data coding and application areas [3]. The light emitter and detector angles are respectively 15°- 30° and up to 15°. Therefore, the two communicating devices must be pointing at each other. The consumed power is very low.

This is a low cost technology, comparatively regulation free and there is no interference with the RF technologies. The optical channel is a drawback, as it needs the devices to be in a line of sight, but it is also an advantage as it provides a comparatively good data transfer safety.

IrDA evolves as a perspective optical wireless communication technology providing data rates 5 and 10 Gigabits per second, at 3 m distance and larger angles.

The IrDA interface is applicable in small autonomous embedded systems, mobile control devices (smartphones, tablets, etc.), medical and industrial equipment, etc. because of the short distance communication.

Many microcontrollers provide built-in IrDA standard support through their UART modules and an additional IR Encoder/Decoder and IR Transceiver - for instance some Microchip's 16-bit and 32-bit microcontrollers [4].

Bluetooth

Bluetooth (IEEE Standard 802.15.1) is initially intended especially to replace the wire cables in computer periphery but nowadays it is also one of the technologies used for wireless connectivity in embedded systems. It uses unlicensed industry, scientific, and medical (ISM) 2.4 GHz radio band [5].

Every Bluetooth has its own address with which the others could identify it. The devices make the connection automatically without any actions of the user.

All the devices in such a Bluetooth system form a so called *piconet*. A master device in a piconet communicates with not more than seven slave devices, and the slave can communicate with the others only through the master. A device could be a member of four piconets at the same time, but only one of them is master. The master acts as a bridge between the piconets. After initiating data transfer, the members of the piconet synchronize their frequencies in a way that they would be in a contact with each other.

The advantages of the Bluetooth technology are small equipment size, easy usage, data safety, good support and development of the standard. Some drawbacks are comparatively high power consumption and impossibility to arrange complex network configurations.

ZigBee

ZigBee (IEEE Standard 802.15.4) is intended for shorter distance range, lower cost, lower power consumption, lower data transfer rates, more compact, and simpler variant of wireless personal area networks (WPANs) in comparison to Bluetooth. It uses the same frequency range of 2,4 GHz [6].

ZigBee realizes various network topologies - star, tree and mesh.

The devices (nodes) in the ZigBee network can be:

- *ZigBee Coordinator*, (one in a piconet) which can communicate with other networks and to save data about its own;
- *ZigBee Router*, which can pass data on from other devices and serves as an intermediate router;
- *ZigBee End Device* – the simplest kind of device, which can communicate only with the above two.

The minimal power consumption is a result of the fact that the slaves are in sleep mode most of the time. They activate for short time intervals only to confirm their presence in the network.

There are four main application areas for ZigBee technology: smart homes, connected lighting, utility industry, zigbee smart energy. The last one is a standard for interoperable products that monitor, control, inform, and automate the delivery and use of energy and water.

Radio-Frequency Identification (RFID)

RFID uses electromagnetic fields to automatically identify and track tags attached to objects.

The typical components of a RFID system are a tag, a reader and an antenna. Various types of tags and readers are used. They can work in several frequency ranges, providing data exchange in different distances: low frequencies (LF) - 125 kHz - 134 kHz, in a distance up to 10 cm; high frequencies (HF) - 13,56 MHz in a distance up to 30 cm; ultra-high frequencies (UHF) 433 MHz and 856 MHz - 960 MHz in a distance up to 100 m; 2450-5800 MHz (microwave) - 1 - 2 m and 3.1–10 GHz ultra-wideband (UWB) - 200 m.

The various frequency ranges of RFID are specified in the ISO/IEC 18000 standard, except the last, which is not standardized. ISO/IEC 14443 and ISO/IEC 15693 define smart card and proximity card interfaces operating in the HF range [7].

The tags are three types: passive, semi-passive and active. *Passive tags* have no their own power supply. They are supplied by the electromagnetic energy received from the reader. That is why the distance allowed is shorter than at the the active - typically to 10 m. *Active tags* (with own power supply - battery) transmit signal to send information stored in the chip at distances up to 100 m. Typically, active tags are used to identify large objects, wagons, containers, etc., which should be monitored over long distances, electronic labels in warehousing, etc. [8].

Active tags themselves are of two types: *transponders*, which are awakened by the reader, switch on their power and response, and *beacons*, which periodically wake, switch on and transmit a signal to the reader.

The semi-passive tags use own power source only to switch on the tag. Unlike active transponders, they have a transmitter. They are used for larger distances and transmit in the frequency range of 850 to 950 MHz.

The common application of RFID technology in the field of embedded systems is in the first two frequency ranges - such as access control, pet identification, tracking of goods, etc. Various forms of tags exist: bracelets, badges, stickers, labels, chips, cards, pins tags for clothing, ampoules for pets chipping, etc.

Although RF technologies in their origin are not appropriate for Internet access, their further development makes it possible [9].

The technology is comparatively easy to implement using microcontrollers with RF transmitters, like Microchip's PIC12/16.

Near Field Communication (NFC)

NFC (ISO/IEC 14443 and ISO/IEC 18000-3) is a modern variety of RFID in the 13,56 MHz frequency range, allowing very short distance communication – up to 10 cm [10]. It is applicable for assets identification, access control, contactless payment, etc.

There are three NFC communication modes:

- NFC peer-to-peer - for data exchange between two paired mobile devices;
- NFC reader/writer - in which one of the devices is active - it sends signals and receives the data sent form the passive device;
- NFC card emulation - NFC-enabled devices like smartphones could be used as credit cards for contactless payment or ticketing.

Initially the technology is designed for access control (identification) and digital tickets in public transportation. Later it is introduced in payment cards (as integrated chips) and smartphones for contactless payment.

NFC is very suitable for configuring of embedded systems using the results of other applications available for smart devices like graphics processing, complex calculations, GPS positioning, Internet communications. Similarly, NFC applies when the smart device wishes to obtain information from an embedded system.

Other useful applications of NFC include passive tags, embedded in advertisement posters and information boards, thereby sending useful information to the users, like scanning QR code.

Smartphones can operate as a reader and as a tag, which makes possible peer-to-peer communication. By holding the smartphone to the NFC-enabled device, the user is able to connect via Bluetooth much faster than pairing devices manually.

The main implementation problems are the proper infrastructure and the data safety.

Z-Wave

Z-Wave is one of the newest wireless technologies in the RF range. It operates in the sub-GHz band, thereby avoiding interference with other wireless technologies in the 2.4 GHz range (Bluetooth, ZigBee, etc.) [11], [12].

It is designed especially for home automation and Internet of Things. A Z-Wave hub (network controller) manages the communication. It allows a distance control via remote web access.

Up to 232 devices could be connected in a mesh network topology in a line of sight up to 100 m. Repeaters (hops) are used in case of obstacles - maximum four hops in a network, increasing the distance up to 200 m.

The devices are interoperable - all they apply ITU-T G.9959 global radio standard and they are compatible, regardless the manufacturer or brand.

Presently over 1700 interoperable Z-Wave products for various home automation applications are available: lighting, lock, various sensors, power management, irrigation, thermostats, etc. Over 70 million products are sold worldwide [12].

WiFi

IEEE wireless network standard WLAN 802.11is initially intended to connect wirelessly mobile devices in a local network, beginning later to be used for Internet connection [13].

While the above wireless standards can be used quite successfully to connect a microcontroller with a periphery for relatively short distances, the WiFi is used in two directions:

- To connect the user with the system using the widely spread mobile devices - smartphones, tablets, laptops, in short distance.

The advantage is that a regular user without professional qualification could easily configure the connection with new devices, unlike ZigBee for instance.

- To connect embedded systems and their blocks with World Wide Web [14];

It is a rapidly growing technology with a great potential. On one hand it gives an opportunity for flexible and rapid monitoring and control of wirelessly connected embedded client devices, so called “Internet of Things” (or “Wireless Connectivity of Things”), and on the other it could be applied successfully together with perspective cloud computing.

Another advantage of WiFi is the high data rate. An amendment to the IEEE 802.11-2007 wireless-networking standard specifies significant increased data rates - from 54 Mbit/s to 600 Mbit/s, using multiple antennas in order to improve network throughput.

It is the most expensive technology in comparison to the above mentioned, but is getting cheaper through the years. In addition, it is significantly cheaper than using a dedicated touch panel for an embedded system.

WiFi is a suitable way to configure and control remotely embedded systems from long distances around the world and from a variety of devices.

Table. 1 presents a short summary of the main features of the above examined short range wireless technologies.

III. Conclusion

A short survey on the features, parameters and application areas of modern wireless technologies has been made in the present paper in relation to embedded systems and more exactly home automation and IoT.

WiFi and Bluetooth, initially designed for office and personal communication, are the most widely used wireless technologies nowadays. They are continually developing under IEEE802 subgroups of standards, effective and reliable, allowing the use of conventional personal digital devices. WiFi is the most expensive approach but the most flexible and extensible. Both technologies are perfect to implement universal man-machine interface.

The features and thus the application areas of the *radio frequency range interfaces* differ. LF devices do not need to communicate in a line of sight. They are intended for short distance, low data transfer communication. The connection is stable close to metal objects, water, etc. unlike HF, UHF and microwave. Their main application areas are objects tracking and positioning, access control, etc.

Modern rapidly developing areas such as building and industrial automation, IoT, sensor networks, imply further development of the wireless interfaces and the emergence of new ones, such as Z-Wave, Wireless Sensor and Actuator Network protocol DASH7, networking protocol for Internet of Things (IoT) Thread, EnOcean and Insteon technologies for home automation, etc.

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TABLE I
MAIN FEATURES OF SHORT RANGE WIRELESS TECHNOLOGIES IN RELATION TO EMBEDDED SYSTEMS APPLICATIONS

Technology	Network topology	Data transfer rate	Wavelength/ Frequency range	Distance, m	Power consumption	Internet connectivity	Smart mobile devices access
Infrared Data Association	peer-to-peer	2,4 kbps-1 Gbps	850–900 nm	0,1-1	low	difficult	not very suitable
Bluetooth	peer-to-peer;star; piconets with up to 7 nodes	1 - 3 Mbps	ISM: 2,4 GHz	0,1 - 100	1 - 100 mW	yes	most suitable
ZigBee	peer-to-peer; star; mesh	250 kbps (20 kbps)	ISM: 2,4 GHz (868 MHz in Europe)	10-100	1 - 100 mW; typically 1 mW	yes	not suitable
RFID	peer-to-peer	LF: 4-8 kbps; HF: 6.7 kbps to 848 kbps	LF: 125–134 kHz HF: 13.56MHz	LF: up to 10 cm HF: up to 100 cm	very low	difficult	not suitable
	peer-to-peer	106, 212 or 424 kbps	13.56MHz	< 20 cm; typical - 4 cm	Tag: none Reader: very low; typically 1 mW	difficult	most suitable
WiFi	star	11 (b), 54 (g), 600 (n) Mbps, (ac) 1,3 Gbps; (ad) 7 Gbps	(n) ISM: 2,4 GHz и/или 5 GHz; (ac) 5 GHz	30-100	highest	excellent	most suitable
ZWAVE	peer-to-peer; mesh, up to 232 nodes	40 - 100 kbps	ISM: 868.42 MHz (Europe)	up to100 m; up to 200 m with 4 hops; typically up to 30m	very low; typically 1 mW	difficult	most suitable

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