IOT SYSTEM FOR EXPERIMENTAL TEACHING

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Abstract

Nowadays still more and more students "suffer" with problems when they are pushed to think creatively. Especially in the field of computer engineering, the students rather use the ready-made libraries, instead of creating something own. It is of course faster, but cutting-edge technologies rarely provide related files. Then the implementation solution lies on the mixture of creativity and experience. In our paper, we focused on the IoT problematic. We are introducing the IoT system built on well-known, Arduino-friendly parts. The system serves as a perfect educational tool for experimental teaching of IoT principles. The system was successfully implemented in the teaching courses for Slovak high-school students as well as for the visiting students from the French university. In the paper, the system structure will be described in detail followed by the discussion about the results of experimental teaching.

Keywords: IoT, Internet-of-Things, programming, ATmega, WiFi, Bluetooth, LoRaWAN.

1 INTRODUCTION

The devices able to detect the various environmental parameters across different application areas are currently becoming more and more a real [1]. Most of these devices are capable of mutual communication and are directly or via some gateway devices integrated into the Internet. In this manner the Internet-of-Things (IoT) is defined. Under the term IoT, we can understand a set of interconnected devices, buildings, vehicles and other objects that are capable of collecting, exchanging and employing information through the embedded electronic systems. In 2013, the Global Standards Initiative on Internet of Things (IoT-GSI) defined IoT as "Information Society Infrastructure."

The idea of interconnected remote devices for increasing safety, operational efficiency and improvement of system operations goes to the 1950s, when the first applications of interconnected distributed sensor systems named "Wireless Sensor Networks (WSN)" were presented. Later, sensor systems were extended to include the action elements that could influence the behaviour of the objects being watched. On this way, "Wireless Networks of Sensors and Actuators (WSAN)" were presented. Each element of such a network, should dispose of a certain amount of "intelligence" - the ability to pre-process the acquired data, secure it and chose the optimal way for sending it to the destination. From WSANs, there is only a step towards the networks, where network elements are named objects which are capable of communication. These interconnected systems were named IoT.

Since the inception of the IoT concept, we have faced another extension of the original definition of the term "object" with a number of interconnected systems extended to humans and animals (e.g. assistive, diagnostic and tracking systems, virtual fences, etc.), processes (cloud-based data processing solutions) and data storages with a huge amount of data.

We are therefore meeting with a new label that better describes the class of interconnected systems, even though it more reminds an advertisement slogan rather than the technical term - "Internet of Everything (IoE)". It is expected that IoE technical resources, software solutions and information, after their interconnection brings besides "terrifying potential", new possibilities and opportunities with far-reaching impact on the structure of the whole society. Every discovery or technological advancement brings with it many benefits in terms of facilitating the life of the individual and thus of the whole society, but at the same time brings the risks of abuse or loss of privacy or a certain restriction of freedom.

A typical IoT system is usually implemented as a sensor network consisted of spatially distributed autonomous sensing elements that communicate with each other [2]. They are located in the monitored area and are continually assessing the state of the monitored object. The term 'subject' is understood in the broadest sense, and it may represent the protected room, a diagnosed production line, the means of transport, and living creature. As many as 99% of the installed sensors...
communicate through electrical conductors. It is expected that in the next 10 years, the WSN / IoT will
be represented in more than 10% of all the installed sensors [3].
With the implementation of the IoT systems, the amount of information available increases, while time
to gather relevant data is now extremely short. Every day, however, the application field of information
technology resources are extended. Based on the previous development, it can be assumed that in
the next decade, the number of IoT applications will increase multiple times. This has an associated
change in paradigms of data processing.
The development of IoT systems is in particular related:
• to the advance of technology in the production of microelectronic systems that enables the
  powerful data processing system integration in a single circuit,
• to advances in the field of sensors, particularly the development of new sensing elements based
  on micro-electro-mechanical systems, MEMS,
• to advances in communication technologies, reliable digital RF-communication systems, short-
  range, low energy consumption, and robust communication links to send data and communicate
  with servers,
• to advances in the field of energy sources and systems for energy harvesting from the
  environment,
• to advances in the processing and analysis of large data - Big Data, Data Mining.
As considering an amount of application fields, IoT is touching almost any kind of our daily activities:
− Automation of households and buildings.
− Intelligent cities.
− Intelligent Production / Factory.
− Automotive industry, transport.
− Wearable electronics.
− Healthcare.
− Precise agriculture.
− Fun electronics.
− Military applications and many more.
With regards to previous, it is necessary not only to talk about the IoT revolution, but also to prepare
the young engineers to be ready to jump on the bandwagon, since the upcoming generation will act as
an actuator of IoT advancements.

2 IOT SYSTEM FOR EXPERIMENTAL TEACHING
The typical IoT scheme consists of the physical layer (hardware), communication layer (RF
communication) and application layer (GUI, cloud, server, databases). Since the WSN, as the IoT
predecessor, is functioning already quite a long time, there is quantum of existing systems available
for developers to facilitate development of new non-traditional applications. The practice requires
application engineers who can effectively use existing systems and data processing platforms as well
as development tools and kits from renowned world manufacturers to quickly and reliably develop the
functioning IoT product. Application GUI could be nowadays simply deployed through different
codeless IoT platforms designed to help to prototype and scale IoT projects through simple
dashboards (Microsoft Azure, ThingWorx, Ubidots, Thingspeak,...). The OpenHW [4] sensory
platforms could suppress the necessity of HW development, since the veritable sensory environment
is very broad and actually ready-to-market solution [5]. Then it is just the software, what is make the
differences between the single solutions.
However, even if to a lesser extent, workers capable of developing technical and program resources
for special applications are needed too. These need to know various RF-ISM wireless communication
systems (WiFi, LoRaWAN 868 and 433 MHz, Bluetooth LE, NFC, etc.) applicable according to
different claims to the coverage, communication speed, reliability and security. Similarly, IoT features
a variety of sensors, signal processing methods, compression and data encryption methods which are
necessary to be recognized especially when atypical, non-traditional applications are developed. Such development assumes that developers will have basic knowledge from sensors physics and logic, circuitry, signal processing, communication technology up to the advanced object oriented programming methodology. In the Figure 1, the basic components mapping the main problems of the development of IoT sensory part are described, since it is just sensory part what makes the IoT system unique.

**Figure 1. Problems to deal with during the IoT system sensory part development.**

To help the students with understanding of IoT problematic, and to help them with the development of their own interesting, non-traditional IoT applications, the special IoT device based on the microcontroller ATmega328 and the communication module (WiFi - ESP12 or LoRaWAN - RFM69 for short distances and RFM95 for distances up to 10km) [6] was developed. Together with the supportive sensor circuitry (RGB LED, Photoresistor and 7-segment display) and extension possibilities provided through 20-pin expansion connectors, it could be said that the low-cost, easy-to-understand, affordable and a kind of universal teaching tool was introduced. Block schematic of the sensor can be seen in the Figure 2.

**Figure 2. Block schematic of the IoT sensor node.**

The proposed IoT system is intended as a basic learning aid to enable the listener to learn the way of solving problems occurred during the development process. To provide students with the additional
features, the IoT system was extended by an application board. The application board interconnects with IoT module through 20-pin connector and contains the sound transducer for piezoacoustic signal generation and 3.3V/5V DC/DC converter aiming at the utilization of low-cost Arduino sensors/modules since most of them work at 5V power supply. It also contains a universal, breadboard, part which could be used for the connection of different sensors and modules. Basic IoT modules supports WiFi communication in 2.4GHz ISM bands, advanced modules are equipped with LoRaWAN radios targeted for the slow, low-energy communication for the long distances in 868MHz and 433MHz ISM bands. Utilization of NFC and BLE protocol could be possible through extension modules. Since the sensor was designed as an OpenHW device, the schematic is shown in the figure below.

![Figure 3. Block schematic of the IoT sensor node - with LoRaWAN modules.](image)

Because the hardware is provided (Figure 4), the main focus of the teaching, or entertainment, lies therefore in the development of software modules, which can differ applications between each other. In addition, students can develop simple hardware add-on modules using the breadboard features of application board, too. The software UART allows students to use the PC as a reference console for application development. This makes the development more user-friendly (Figure 5).

![Figure 4. IoT sensor node with a) LoRaWAN and b) WiFi radio.](image)
The main control unit of the IoT system, microcontroller made by Atmel - ATmega328, was chosen due to the good ratio between the price and performance which is suitable for educational purposes. Moreover, Atmel provides free integrated development environment Atmel Studio 7.0 [7] which allows development and easy implementation of software written in C or C++ language. The IDE can be easily downloaded from the Atmel webpage. The selected microcontroller is also widely used within the popular Arduino development platform, therefore it also comprise a huge community of programmers publishing example codes, libraries, and other supportive materials making the work with this microcontroller very simple. The open-source Arduino IDE [8] or online IDE can be also used with the IoT system.

3 TEACHING COURSE

The system was tested in March 2017, when 70 students from around 30 high-schools in Slovakia and 14 students from 1 France school of CNAM type came to our University to participate in the IoT workshop which was organized for the testing purposes and lasted for one week (Figure 6). The course was based on the implementation of IoT system development kit for the purposes of teaching and motivating the students for making their own application. Here it could be stressed, that around 50% of students was programming the software in C Language for the first time.

During the workshop we wanted to learn the students about the opportunities brought by the IoT field. We wanted to show the variety of problems that need to be addressed during the development of new,
non-traditional application. Other aim was also to show the students the difference between the IoT user in opposite to the developer of IoT applications. According to these assumptions, following program for students was applied:

1. Introduction of IoT problematic.
2. Description of the IoT Sensor - hardware, IDE.
3. Programming of the basic functions "RGB LED operation" - displaying of _uint_8 data.
4. Timer, A/D converter (ADC), Battery status read, Interrupt subsystem.
5. Displaying the data together with A/D conversion using the interrupt subsystem.
6. Operation of the light intensity sensor.
7. AT commands and control of the ESP-12 Wi-Fi module.
8. The WiFi module in the client function (ST - Station mode).
9. The WiFi module in the server function (AP - Access Point mode).
10. The WiFi module in the WEB server function.
12. Presentation of the developed application.

4 CONCLUSION

The students, which participated at the workshop, went successfully through all assigned tasks, even when they met with C-Language-programming for the first time in their life. The students worked in the groups, what facilitates the understanding of the lectures. As the final application, all of the students were able to configure the sensors for measuring the light intensity in environment. This information was then sent through the local WiFi network to the public IoT cloud Thingspeak, where the data analysis was performed. Students were during the work really enthusiastic, because they really liked to work with the real hardware opposite to the traditional simulations. According to these findings, we can consider our way of teaching IoT deployment as a kind of succesfull.

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REFERENCES
