

PAPER • OPEN ACCESS

## Development of an Educational Kit for Learning IoT

To cite this article: Iliia Lyzhin *et al* 2019 *J. Phys.: Conf. Ser.* **1163** 012015

View the [article online](#) for updates and enhancements.



**IOP | ebooks™**

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the [collection](#) - download the first chapter of every title for free.

# Development of an Educational Kit for Learning IoT

**Iliya Lyzhin, Sergey Efremov, Alexey Rolich, Leonid Voskov, Dmitrii Abrameshin**

National Research University Higher School of Economics, Moscow 123458, Russia

E-mail: lyzhin.iliya@gmail.com

**Abstract.** The primary purpose of this paper is to provide an overview of existing education solutions for IoT and develop proposals for their improvement. The study draws analysis of current conditions of the educational IoT sphere, a comparative analysis of educational products used for teaching of undergraduate students. With that the article describes the architecture of our own software and hardware platform for learning IOT. Moreover, this paper reviews methods and technical instruments employed to design software and hardware appliances.

## 1. Introduction

Today more and more electronic devices are designed with a built-in access to a global network, this concept is widely known as the Internet of Things (IoT). With many isolated infrastructures of such devices, there is a growing need in integration of these smart things into a single network, development of rules for their interconnection and determination of interaction scenarios [1].

The educational side of the Internet of Things is still very much in development. With existing courses at the university level related to electrical, electronic engineering, programming, microcontroller architectures, robotics, data storage and analysis and others it is very much an open question of whether teaching IoT requires something in addition. Having analyzed the related works we have concluded that the general approach to teaching IoT is to design extensible educational constructors for carrying out multidisciplinary practice sessions. Hence the main goal of this paper is to provide an overview of the work that has been done in this direction so far and to present our own proposals.

This paper is based on the results of a project carried out by our research group, which aims at designing a hardware-software appliance (IoT constructor) that would provide an improved way of teaching embedded solutions and Internet of Things.

The following tasks are solved sequentially to achieve the stated goal:

- Systematic review and comparison of existing technical solutions
- Development of a physical architecture for the hardware-software appliance
- Design of hardware components
- Development of software components

The key novelty of the study is a complex approach to the already created educational constructors and development of a device, being both optimal in economic and technical terms and capable of direct interactions with a network as compared to those emulating this process.

## 2. Related works

The problem of choosing efficient instruments for IoT education has already been extensively studied by different authors. Specifically, it has been addressed by researchers from the University of Novi Sad, Serbia [2] who suggested a package created for university education. This pack is based upon



Arduino/Genuino UNO Rev3 and Ethernet Shield, in addition, a set of breadboards and jumper wires are used for attachment of sensors. In accordance with the information provided by the authors, the cost of the kit without sensors varies from 11.89 to 57.5 euros. The prospects of further advancement are seen in integration of Wi-Fi, ZigBee, RS-232 modules and other communication technologies.

At the same time, staff members of the College of Engineering and Technology, Hubballi, Karnataka, India have created a multidisciplinary IoT course for their educational establishment [3]. From the technical point of view, the course is based on the Intel Galileo board, Arduino-Uno, Raspberry Pi-2. For data transmission GSM, Wi-fi and Ethernet are used. During the course students are suggested to solve cases using the backend tools and equipment enumerated above. The possible versions of tasks are the creation of prototype of IoT device or the development of user interface including Django framework and integration with outside cloud-hosted services.

Research results show that during the course 75% of student groups have applied cloud services, while 25% have used notification function for mobile devices. Authors point out that during the studies mentioned learners have attained basic knowledge of developing systems in IoT sphere.

In addition to that, the educational programme contains both hardware and software learning practices including the integration of devices into an existing cloud infrastructure. In particular, students designed the following applications: smart lighting, smart irrigation, weather reporting bot and other projects in the IoT sphere.

This example illustrates the fact that, taking part in multidisciplinary course in specialized secondary education institution may contribute to the creation of notable and practically oriented projects in case the course programme is thoroughly designed and suitable technical means of learning are available.

Another notable study has been conducted by P. Plaza et al [4]. Their work includes the comparative analysis of PCBs, such as Arduino WiFi Shield, Arduino Yún Shield, Arduino MKR1000, Node MCU ESP8266 and Onion Omega. The following features have been revealed:

- The higher amount of memory (both volatile and non-volatile) is associated with the Genuino Yún Shield and the Onion Omega, while lower amount is incorporated in the Genuino MKR1000.
- The majority of programming languages are supported by the Node MCU ESP8266 and the Onion Omega.
- The least expensive board is the NodeMCU ESP8266, while the costliest one is the Arduino WiFi Shield.

Researchers have concluded that any of enumerated devices are appropriate in the context of IoT education. Specifically, it should be noted that the NodeMCU ESP8266 is 2.25 times less expensive than the Onion Omega and 5 times less expensive than the Genuino Yún Shield.

The Maze game [5] has been created in the context of a student project called «Connection systems» and may be useful for education in both IoT and robotic systems spheres. The basic idea of the activity is a competition of different robotic devices in finding an exit from a labyrinth. The programmers aimed to make the system able to work with ESP-12E, ESPDuino, D1, NodeMCU, ESP8266-01, Wee, Arduino, C.H.I.P.

Authors claim that their product may be employed for educational purposes. The equipment used in project is of low cost and can be easily modified; moreover, there are open libraries of functions. The noteworthy aspect is that 5 out of 8 applied devices are based on the ESP8266 microcontroller.

Overall, these studies consistently indicate that the popularity of technologies application in education in IoT sphere is widespread. Furthermore, the reviewed works suggest that the development of educational projects and learning kits is mainly done with a help of Arduino or PCBs based on the ESP8266. Single-board computers (such as, Raspberry Pi-2 and Onion Omega) are employed a bit less frequently.

As a result of the analysis of current technical solutions and their strengths and weaknesses, the requirement for considered product has been elaborated. The major point is that our device is going to be different from the current analogues in a way that it will have wireless connection to the Internet, larger embedded memory and a built-in support for cloud integration. A detailed table of comparative analysis can be found in A.1. [6]

### **3. Proposal of a new IoT constructor**

#### *3.1. Hardware*

The literature review has revealed that in the context of IoT DIY constructors the most widely used boards are Arduino or PCBs based on ESP8266. We plan to extend this list by using the Wemos D1 to develop a new constructor as it supports the Arduino IDE, sensors and partly supports libraries for Arduino projects.

At the same time, the Wemos D1 provides a Wi-Fi connection and costs less than a similar Arduino PCB. The more in-depth results of boards comparison are given in Appendices, Table 2. Consequently, Wemos D1 having both cost-effectiveness and optimal technical characteristics was considered as appropriate for the new product.

The constructor would include the Wemos D1 PCB, a board for module's fastening, a PCB case, specially created magnetic contacts, sensors (collecting data on lighting, temperature and vibration), actuating devices (ordinary and addressable RGB LEDs, relay for switching high-voltage appliances).

The capacity of our university's Laboratory for 3D modelling and visualization is planned to be used for development of terminals and bodies of device.

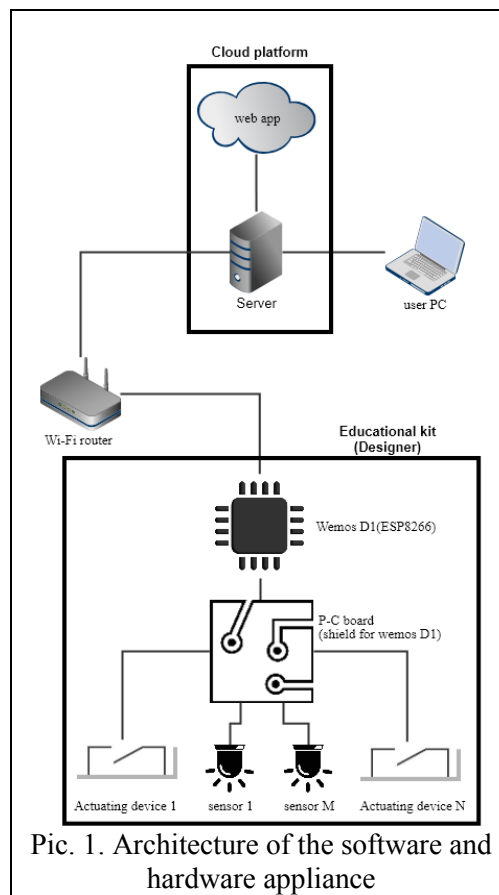
#### *3.2. Software*

Data collected by sensors will be transmitted through the wireless IEEE 802.11 network to the cloud platform. The platform will accumulate data and send back commands for actuators based on the programmable interconnection scenarios.

For the development of the cloud platform the Separate template engine [7] has been chosen as it has the following advantages: relatively insignificant size, concise syntax, provided with extensive documentation and produced under of free license of MIT. Twitter Bootstrap has been selected for the visual web design because of its wide recognition and compatibility with all existing browsers.

As for data storage we plan to use two database types – a relational database for storing device descriptors and user data and a NoSQL database for storing unstructured sensor data. We have chosen MySQL as a relational database as it is supported by the majority of hosting services and it has proven itself efficient in the web development sphere. The unstructured data storage is still at the stage of comparison of existing solutions and testing.

It is further anticipated that the new platform will involve a preconfigured server and web-application with user interface. Moreover, there would be functions of registration and authorization, addition and configuration of devices, device sharing, scenario editor and interactive tutorials provided.



Pic. 1. Architecture of the software and hardware appliance

#### 4. Conclusions

In this paper we have made an attempt to bring together existing approaches to developing IoT solutions that can be used for educational purposes. Motivated by the greatly increasing demand from the educational sphere related to teaching IoT, we have reviewed the work done so far and presented an architecture of a novel IoT constructor and built its first prototype.

*Acknowledgments.* The article was prepared within the framework of the Academic Fund Program at the National Research University Higher School of Economics (HSE) in 2017 — 2018 (grant № 17-05-0017) and by the Russian Academic Excellence Project «5-100».

#### 5. Appendices

**Table 1.** Comparison of the existing educational kits

Criteria\Product	Skart-LAB "Umnyj dom"[8]	Skretchduino.La boratorija[9]	Jodo[10]	LAZY SMART LS Monitoring[11]	IoT Smart Agriculture[12]	Obrazovatel'naja laboratorija JS "Internet veshhej"[13]
Controller	ATmega2560	ATmega328	Cortex-M4	ATmega1280	ATmega328	Atmega
Internet connection	-	-	-	+(GSM/GPRS)	+(Ethernet)	-
Number of sensors	9	2	4	1	4	9
Number of supported programming languages	1	4	1	1	1	1

Availability of cloud platform	-	-	-	+	-	-
Possibility to connect actuating devices	+	-	+	+	+	+
Configurator manager	-	-	-	+	-	-
Price (EUR)	274	124	65	47	72	871

**Table 2.** Results of PCB comparison

Criteria\P-c board	Arduino Uno	Arduino Leonardo ETH	Arduino M0	Iskra JS	PSoC 4200	IFLAT-32 v2.0	WeMos D1
Controller	ATmega328p	ATmega32U4	Cortex M0	Cortex-M4	Cortex M0	ARM 7	ESP8266EX
Frequency	16 MHz	16 MHz	48 MHz	168 MHz	48 MHz	72 MHz	80 Hz
RAM	2 kB	2.5 kB	32 kB	192 kB	4 kB	96 kB	80 kB
Memory	32 kB	32 kB	256 kB	1 mB	32 kB	12 kB	4 mB
Digital pins	14	8	14	14	36	54	11
Analog pins	6	12	6	12	0	6	1
I2C	+	+	+	+	+	+	+
Ethernet	-	+	-	-	-	-	-
Wi-fi	-	-	-	-	-	-	+
Price (EUR)	13	48	26	22	19	30	6,50

## 6. References

- [1] Efremov S., Pilipenko N., Voskov L. An integrated approach to common problems in the Internet of Things, in: *Procedia Engineering Vol. 100: 25th DAAAM International Symposium on Intelligent Manufacturing and Automation*, 2014. Switzerland : Elsevier, 2015. P. 1215-1223.
- [2] Dobrilovic D., Zeljko S. Design of open-source platform for introducing Internet of Things in university curriculum. *C. IEEE 11th Int. Symp. on SACI* Timisoara, Romania, 2016, p. 273-6
- [3] Raikar M. M., Desai P., Naragund J. G.. Active Learning Explored in Open Elective Course: Internet of Things (IoT). *C. IEEE T4E* Mumbai, India, 2016, pp. 15-18
- [4] Plaza, Pedro, et al. Wireless Development Boards to Connect the World. *Online Engineering & Internet of Things. J. Lec. Notes in Net. and Sys., Springer Int. Pub.* 2018, vol. **22**, pp.19-27
- [5] Dobrilovic D. et al. Building ESP8266 Wi-Fi module network based on open-source hardware and single-board computers. *C MECHEDU* 2017. Serbia, 2017, pp.101-6
- [6] Lyzhin I.G. Obrazovatel'nye konstruktory v sfere internet veshhej (IoT). *C Innovacionnoe razvitie rossijskoj jekonomiki* Moscow, 2017, vol. **5**, pp. 397-9
- [7] Separate is a modern open-source Template Engine for PHP Available at: <http://separate.esud.info/> (accessed 28 February 2018)
- [8] SCART Available at: <http://skartshop.ru/konstruktory-skart/konstruktory-skart/product/view/42/220> (accessed 28 February 2018)
- [9] Skretch Laboratoriya Available at: [http://www.linuxcenter.ru/shop/ops\\_hard/scratch/scratch\\_lab/](http://www.linuxcenter.ru/shop/ops_hard/scratch/scratch_lab/) (accessed 28 February 2018)
- [10] Amperka. Jodo. Available at: <http://amperka.ru/product/yodo/> (accessed 28 February 2018)
- [11] Lazy Smart: LS Monitoring Available at: <http://lazysmart.ru/LSMonitor> (accessed 28 February 2018)
- [12] Mgbot. IoT Smart Agriculture Available at: <https://mgbot.ru/catalog/iot/bazovyj-uchebnyj-komplekt-iot-smart-agriculture> (accessed 28 February 2018)
- [13] SCART Available at: <http://skartshop.ru/6-10-let/product/view/47/247> (accessed 28 February 2018)