Wireless Development Boards to Connect the World

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Abstract. Nowadays, Wireless applications are widely extended in the Scientific, Education and Hobbyist communities. The aim of this paper is to provide a review of some of the most popular boards which allow an ease way to develop a wide range of applications related to STEM (Science, Technology, Engineering and Mathematics) in an educational manner. Moreover, the scope is focused on those development boards which allow Wireless communications in order to perform Things which can be integrated into an Internet of Things environment. Arduino WiFi Shield, Arduino Yún Shield, Arduino MKR1000, NodeMCU ESP8266 and Onion Omega have been analyzed, compared and discussed. The analysis has been carried out attending on the Built-in Hardware, the Programmer Interface, the connection possibilities and the Developer Community which is behind the corresponding board.

Keywords: IoT · Wireless · Robotics · Education · STEM

1 Introduction

The aim of this paper is to present some of the current development boards which can be used to deploy IoT (Internet of Things) applications within an STEM (Science, Technology, Engineering and Mathematics) educational environment.

Nowadays, there are a wide range of development boards which can be classified in several ways. According to [1], the development platforms can be categorized in four groups:

- Based on Microcontrollers,
- based on Microprocessors,
- based on FPGA (Field Programmable Gate Array), and
- Hybrid Development Platforms.

The IoT (Internet of Things) movement has impacted on the traditional Development Boards. There are lots of IoT based applications which are being developed in many different fields [2]. Some examples are [3] in Emergency Medical Services, [4] in Cloud Computing and [5] in Remote Educational laboratories.

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The Arduino WiFi Shield provides to the Arduino board a wirelessly internet connection [6]. It cannot work in a stand-alone mode. Hence, this board requires a microcontroller to interact with other elements.

The Yún Shield easily brings the Yún features to Arduino and Genuino boards. It is a good choice for IoT projects using wireless connection to access the internet [6].

Genuino MKR1000 is a powerful board that combines the functionality of the Zero and the Wi-Fi Shield. It is the ideal solution for makers wanting to design IoT projects with minimal previous experience in networking [6].

This board is an Open Source Firmware and development kit that helps the IoT product prototyping within a few Lua script lines [7].

The Onion Omega is a Hardware development platform with built-in WiFi and a full Linux Operating System [8].

There are a vast variety of software development platforms which can be used as core of IoT applications. Some of them are cost-effective platforms such as the mentioned in this paper. Furthermore, these platforms can be easily included with the aim of elaborating robotic educational activities where the proactive learning is empowered through experiments in the real world.

This paper is divided in four sections. Section 2 presents the analyzed IoT development boards. Section 3 compares all of them. The last section summarizes the achieved conclusions after the performed investigation.

2 Wireless Development Boards

2.1 Arduino and Genuino IoT Boards

Arduino is an Open Source Hardware and Software project. Additionally, Arduino is supported by a user community that designs and manufactures devices and interactive objects, and it is worldwide extended and growing day by day [6]. There are four development boards provided by Arduino for IoT purposes: Arduino WiFi Shield, Arduino Yún Shield and Arduino MKR1000. Along this section all of them are analyzed. All of them are programmed using the Arduino Software IDE (Integrated Development Environment). The Arduino language is based on C/C++. It links against AVR Libc and allows the use of any of its functions. The Arduino IDE is produced for the following operating systems: Windows, Mac OS (operative System), Linux. Additionally, a portable IDE can be used for Windows and Linux. Every element of the mentioned platforms in this section – Hardware, Software and documentation – is freely available and open-source.

Arduino boards are intended for United States meanwhile Genuino is the sister brand for products which are sold outside the United States.

The Arduino WiFi Shield provide a wirelessly connection to Arduino boards. The connection is established by following a few simple instructions in order to connect Things through the internet. This board presents the following characteristics:

- It is based on the HDG204 Wireless LAN (Local Area Network) 802.11b/g System in-Package.

- There is an onboard micro-SD card slot, which can be used to store files for serving over the network.
- The board mechanical data are: Length: 63.2 mm and width: 53.5 mm.
- The Arduino WiFi Shield board cost is 69.00 € [6].

In the same way than Arduino WiFi Shield, the Yún Shield extends the Arduino board with the power of a Linux based system which enables advanced network connections and applications. This board presents the following characteristics:

- Yún Web Panel and the "YunFirstConfig" sketch can be used to connect through WiFi or wired network (Ethernet) in a simple way.
- The Shield preferences and sketch uploading can be performed directly from the attached Arduino/Genuino board.
- The board mechanical data are: Length: 68.6 mm and width: 53.3 mm.
- The Genuino Yún Shield board cost is 39.90 € [6].

Genuino MKR1000 has been designed to offer a practical and cost effective solution for projects which require Wi-Fi connectivity. This board presents the following characteristics:

- It is based on the Atmel ATSAMW25 SoC (System on Chip).
- This processor is part of the SmartConnect family of Atmel Wireless devices. SmartConnect family is specifically designed for IoT projects.
- The ATSAMW25 includes also a single 1×1 stream PCB (Printed Circuit Board) Antenna.
- The board includes a Li-Po charging circuit which allows the use of a Li-Po battery as external power. Additionally, a 5 V external power supply is allowed. Internally, the MKR1000 switches automatically from both supply sources.
- The board mechanical data are: Length: 65.0 mm and width: 25.0 mm.
- The Genuino MKR1000 board cost is 31.99 € [6].

2.2 NodeMCU ESP8266

NodeMCU is an open source IoT platform. The term NodeMCU refers to the Firmware. This board presents the following characteristics:

- The Lua scripting language is used for programming the board. It is based on the eLua project.
- The Development Kit is based on ESP8266, integrates GPIO (General Purpose Input Output), PWM, IIC, 1-Wire and ADC all in the same board.
- The board mechanical data are: Length: 38.0 mm and width: 25.0 mm.
- The NodeMCU ESP8266 board cost is 7.95 € [9].

2.3 Onion Omega

This board includes a built-in WiFi, it is Arduino-compatible and a Linux is running inside. This board presents the following characteristics:

- It lets the Hardware prototyping using familiar tools such as Git, pip, npm.

- High level programming languages such as Python, Javascript, PHP can be used.
- The Onion Omega is fully integrated with the Onion Cloud with the aim of creating Internet of Things applications.
- It is Open Source. The processor is the Qualcomm Atheros AR9331 SoC.
- The board mechanical data are: Length: 42.7 mm and width: 26.4 mm.
- The Onion Omega board cost is 19.99 $ [10]. Using [11] for currency conversion from United States dollars to Euros the board cost is 17.94 €.

3 Discussion

Along the previous sections seven IoT development platforms have been analyzed with the aim of knowing about the Built-in Hardware, the Programmer Interface, the connection possibilities and the Developer Community which is behind the corresponding board.

There are two types of Arduino/Genuino IoT boards: Shield boards and the full-integrated boards. The Shield boards require an additional microcontroller in order to interact with other elements such as sensors or actuators which are widely used in robotic education. On the other hand, NodeMCU and Onion Omega can be used in a stand-alone mode. Table 1 summarizes the microcontroller and processor for each board.

Table 1. IoT development board processing device.

IoT development board	Microcontroller	Processor
Arduino WiFi Shield	Atmel AT32UC3	None
Genuino Yún Shield	None	Atheros AR9331
Genuino MKR1000	SAMD21 Cortex-M0+	None
NodeMCU ESP8266	None	Tensilica Xtensa LX106
Onion Omega	None	Big-Endian

With the aim of powering the boards, it is important to know what is voltage level for each one in order to adapt levels from the board to other connected devices. Table 2 lists the IoT development boards and the voltage for the power supply and the input and output port interfaces.

Other important characteristic for the development is the available memory. The presented boards include different kind of memory resources, Table 3 compiles which type of memory – volatile and non-volatile - is available and how much memory can be used.

In common applications, IoT boards should interface with other devices using a wired connection. These communications usually are performed using a serial interface. Furthermore, digital and analog ports are used in order to read sensor values or interact with some kind of actuators. Table 4 summarizes the serial and port interfaces which can be performed for each IoT board.

Table 2. IoT development board power supply and port interface voltage level.

IoT development board	Power supply	Input/Output voltage
Arduino WiFi Shield	5 V externally	There is not Input/Output port interface
Genuino Yún Shield	3.3 V	There is not Input/Output port interface
Genuino MKR1000	5 V or Li-Po single cell, 3.7 V, 700 mAh minimum	3.3 V
NodeMCU ESP8266	5 V from USB or 3.3 V from VIN	3.3 V
Onion Omega	5 V from USB or 3.3 V from VIN	3.3 V

Table 3. IoT development board: volatile and non-volatile resources.

IoT development board	Volatile memory	Non-volatile memory
Arduino WiFi Shield	Internal SRAM: 64 KB	Internal flash: 512 KB on-board micro SD slot
Genuino Yún Shield	RAM: 64 MB DDR2	Flash: 16 MB on-board micro SD slot
Genuino MKR1000	Internal SRAM: 32 KB	Internal flash: 256 KB
NodeMCU ESP8266	Internal RAM: 64 KB for instructions Internal RAM: 96 KB for data	QSPI flash: 512 KB to 4 MB
Onion Omega	RAM: 64 MB DDR2	Flash: 16 MB

Table 4. IoT development board; serial and port interfaces.

IoT development board	Serial interfaces	Discrete ports
Arduino WiFi Shield	SPI, USB, ICSP, UART and FTDI	None
Genuino Yún Shield	SPI, USB, ICSP and UART	None
Genuino MKR1000	SPI, I2C, and UART	Digital I/O pins: 8 PWM output: 12 Analog input pins: 7 (ADC 8/10/12 bit) Analog output pin: 1 (DAC 10 bit)
NodeMCU ESP8266	SPI, I2C, I2S and UART	Digital I/O pins: 10 (can be used for PWM, I2C, 1-wire) Analog input pin: 1 (ADC 10 bit)
Onion Omega	SPI, I2S and UART	Digital I/O pins: 18

When there are Hardware and Software developments, the software required for programming the board and the used language are very important elements. Table 5 states the IoT development board programming software and the used language for programming them.

Table 5. IoT development board; programming tool and language.

IoT development board	Programming tool	Programming language
Arduino WiFi Shield	Arduino IDE	Arduino language (based on C/C++)
Genuino Yún Shield	Arduino IDE, Web interface	Arduino language (based on C/C++), Python
Genuino MKR1000	Arduino IDE	Arduino language (based on C/C++)
NodeMCU ESP8266	NodeMCU Firmware, Arduino IDE	Simple LUA based programming language, Arduino language (based on C/C++)
Onion Omega	Serial terminal, SSH terminal	Python, Javascript, PHP

Other important specification for any application is the size restriction. None of the analyzed boards are very large, the larger one has a length of 68.6 mm and a width of 53.3 mm - Genuino Yún Shield – and the smallest one is sized with a length of 38.0 mm and a width of 25.0 mm - NodeMCU ESP8266. Table 6 compares the IoT development boards dimensions.

Table 6. IoT development board dimensions.

IoT development board	Length	Width
Arduino WiFi Shield	63.2 mm	53.5 mm
Genuino Yún Shield	68.6 mm	53.3 mm
Genuino MKR1000	65.0 mm	25.0 mm
NodeMCU ESP8266	38.0 mm	25.0 mm
Onion Omega	42.7 mm	26.4 mm

Moreover, the board cost is compared too. Due to the project funding, the cost is an important aspect which should be have in mind. As it can be seen, none of them are especially expensive, the most expensive board costs 69.00 € - Arduino WiFi Shield – and the cheapest one costs 7.95 € - NodeMCU ESP8266. All of them are affordable for majority of projects. Table 7 specifies the IoT development boards cost.

Furthermore, other important aspect is getting support during the development, communities are very useful. Traditionally, manufacturers provided some telephone or some e-mail for this purpose. Nowadays, most of manufacturers include a forum with the aim of providing support to their customers. These forums are built by company's

Table 7. IoT development board cost.

IoT development board	Cost
Arduino WiFi Shield	69.00 €
Genuino Yún Shield	39.90 €
Genuino MKR1000	31.99 €
NodeMCU ESP8266	7.95 €
Onion Omega	17.94 €

experts and the customers and all of them form a community for the corresponding product.

Arduino WiFi Shield, Arduino Yún Shield and Arduino MKR1000 are supported by the Arduino community [12]. NodeMCU ESP8266 is supported by two communities: NodeMCU community [13] and ESP8266 community [14]. Onion Omega is supported by the Onion community [15].

Finally, when a development is started it is important to get references about things what other people has made and the way they are using the development boards. Arduino projects are widely extended to scientific community, professionals and hobbyists [16] presents a body area network, for acquiring data related to body position and some simple movements based on a WiFi Shield stacked on an Arduino ChipKIT MAX32 [17] describes a low-cost Wi-Fi sensor network based on ESP8266. Enable monitoring of heart pulse sensor data on the cloud with ESP8266 is detailed in [18].

Using one of the described IoT development boards, mobile robots can be used as remote laboratory in order to teach computer science in a similar way that is described in [19, 20]. It can be used as a guide for using IoT as a TEL (Technology Enhanced Learning) tool.

4 Conclusions

The result of this work shows the results of the analyzed IoT development boards that can be introduced easily in classrooms within a STEM context. Performed educational activities using the mentioned platforms are also considered. Hence, recommendations are included with the aim of easing the inclusion of one of them in a classroom.

Any of this IoT development boards can be used in classrooms or remotely in order to provide an easy way with the aim of including robotics within a STEM context. Additionally, they allow making homemade applications framed in a DIY (Do It Yourself) context.

Presented analysis is part of the state of the art of a doctoral thesis; a novel approach to collaborative robotic educational tool is being developed. An Open Hardware platform that can be used in classrooms with aim of developing educational programs related to robotics in a collaborative environment which promotes innovation and motivation for students during the learning process 1. The platform which is being developed presents wirelessly connections such as Bluetooth a WiFi as enhancements 2. The Wireless connection is provided by a WiFi development board which is integrated as part of the collaborative robotic educational tool. The doctoral thesis is being carried out in the Engineering Industrial School of UNED (Spanish University for Distance Education) and the Electrical and Computer Engineering Department (DIEEC).

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