An Internet-of-Things Educational Platform

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Summary
The Internet of Things (IoT) is a rapidly growing computing technology that enables the development of a variety of smart applications in different domains. The education sector has realized the IoT technological revolution and the rising demand of IoT education. Nowadays a number of academic programs involving IoT have been introduced worldwide. However, effective IoT education would require moving the teaching-learning process to a more interactive and practical level. This feasible consideration in addition to the interdisciplinary nature of IoT make it challenging to have effective IoT education. Therefore, having hands-on and practice-based IoT education will not only enrich IoT learning experience and improve student skills, but also open the doors to enable effective and collaborative IoT education. This work aims at the development of an effective platform for practical and interactive education of the IoT technology. The focus is on designing and implementing a simple-to-use IoT educational platform using cost-effective software and hardware components. The system was evaluated following the Technology Acceptance Model (TAM) and the results indicated the simplicity and efficiency of the system and its positive impact on users' behavior and attitudes toward practical IoT education.

Key words:
Internet of Things, Wireless Sensor Networks, Educational Platform, IoT Cloud.

1. Introduction

Internet of Things (IoT) is a technological revolution that enables the convergence of the physical and digital worlds over the Internet. It comes to have significant impact on our lives and starts to have influence over different governmental, industrial and commercial sectors. This has led to a growing interest in the developments of different IoT applications such as smart home, city, and factories. The number of real IoT deployments of these applications is increasing in the different parts of the world. The same goes for the number of IoT-connected physical devices which is expected to continue increasing to hit billions in the near future. This would increase the demand of IoT developers and specialists in the different domains.

The education sector has realized the evolving IoT technology and recognized the need for IoT education. As a result, a number of universities around the world have started to teach the IoT technology. Nowadays, many computer colleges and schools have included IoT courses in their curriculums while others offer a complete degree on IoT. However, it is important to advance the IoT teaching-learning process in a way that can guarantee optimal outcome. This is evident as IoT is an emerging and evolving technology that is inherently interdisciplinary and requires the understanding of a number of computing disciplines such as wireless networking, cloud computing, and data processing. These IoT concepts would be challenges for different kinds of people of different ages. Therefore, teaching IoT needs a more practical and interactive educational approach. For novice learners, it is evident that there is a need for simple-to-use and easy-to-access educational environment to learn IoT. Using conventional education methods would make the learning process of IoT become more challenging. It would be ineffective to introduce conventional courses to introduce the development of IoT applications and systems. It is important to introduce interactivity to the learning process to enhance learners experience and increase teacher-student interaction and cooperation. Having it with hands-on and very interactive experience would improve the learning process. This can also enables collaborative learning and enhance students’ skills and knowledge.

This paper addresses this challenge and presents the design and implementation of an effective and easy-to-use IoT educational platform. The main objective is to enable an effective and practical IoT teaching-learning process in an interactive and motivating educational environment. The platform design provides scalable, flexible, modular, reconfigurable, and portable system. It enables a cost-effective educational tool that can be easily integrated into the curriculum. The proposed IoT educational platform introduces the IoT technology in simple and interactive educational approach. It also provides students with easy ways to practically experiment various IoT concepts and use their ingenuity to design different IoT applications. The platform can be customized to introduce different IoT aspects at different levels targeting both academic and public interests. The system helps stakeholders to enhance IoT educational practice and improves students' success factor, behavior, and attitudes toward practical IoT education.

The paper is structured to give an overview of the IoT technology and education in the following section. Section 3 discusses the main requirements of the system. In Section 4 and 5, the design and implementation of the IoT

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Educational Platform are presented, respectively. Section 6 gives some potential educational use cases of the system. In Section 7, the evaluation of the system is described and the evaluation results are presented. Section 8 concludes this paper.

2. Literature Review

2.1 IoT Overview

IoT expands the current Internet to interconnect most of the physical objects around the world. It realizes the possibility of connecting the things around us to the internet and developing a wide range of new smart applications. This makes a step towards digital intelligence and enables smart automation without the need for human intervention.

Given the nature of IoT and merging the physical and virtual worlds, the possibilities and opportunities are extremely broad. The IoT technology has been applied to develop a wide range of smart applications including smart home, city, health, parking, campus and many other applications in different domains such as agriculture, surveillance, transportation, and military. Applications of smart city, for example, facilitate intelligent city management in regards to many aspects such as traffic, life style, daily services, and so on to improve life quality in an effective way. IoT can also be used to interconnect vehicles in an intelligent transportation system. This would facilitate remote monitoring of traffic to enhance driving experience.

IoT applications involve the deployment of a large amount of interconnected IoT nodes with the capabilities of sensing and collecting data and the ability to share information as depicted in Fig 1. Therefore, IoT relies on a number of key components to have objects connected to the Internet and accessed remotely in an efficient manner. Sensors and actuators in addition to low power wireless communication modules are essential components for data collection and transmission to the Internet. There are a wide range of sensors such as temperature, pressure, light intensity detectors, humidity, and proximity detection. An Example of low power wireless communication technology is Zigbee which was developed by the Zigbee Alliance. It operates on top of the IEEE 802.15.4standard and designed to operate short-range low-rate wireless radio communication. Zigbee supports different topology models including the star and mesh topology. Other examples include Bluetooth Low Energy (BLE), 6LoWPAN and LoRAWAN. Using one of these technologies, IoT objects can be interconnected in a wireless sensor network for simple interconnectivity and power-saving setup. However, a gateway device is required in such a setup to interconnect different network protocols to the Internet. Gateways can also be configured to perform local pre-processing of the collected sensor data before transmitting it to the cloud for further application-specific data management and analysis.

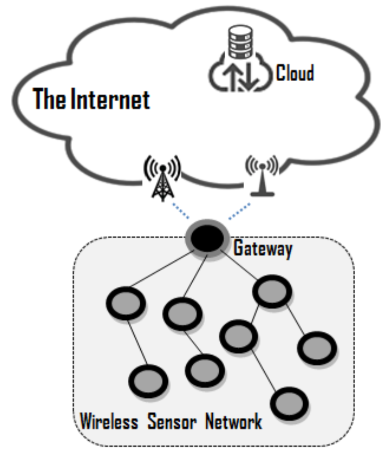

Fig. 1 Typical IoT Deployment.

2.2 IoT Education

There has been a growing interest in having IoT on the computing curriculum and educating students the principles of the IoT technology. To make this more effective and practical, a number of research efforts have been made to develop and deploy different IoT educational platforms and facilitate more interactive IoT teaching-learning process. In [1], an Innovative Experimental Platform was developed to enable practical and creative IoT curriculums. It was used for experimental and practice teaching at Zhongkai University of Agriculture and Engineering and Guilin University of Technology. In [2], a comprehensive IoT teaching approach taking students from basic to advance IoT concepts was presented. It was highly based on practical and experimental learning-teaching process using the Cisco Packet Tracer software and FIWARE IoT platform for building virtual and real IoT applications and systems. Another practical experience for teaching the IoT technology was introduced at Kookmin University in Korea [3]. It focused on Hands-On Tutorials (HOT) to develop practical IoT skills by analyzing selected samples of IoT applications. It incorporates the design of basic IoT systems and implementation of the different IoT concepts using the Microsoft Lab of Things platform. In [4], the intelligence of learning things (IoLT) educational platform is proposed. It is based on an IoT-based blended learning approach with a three-tier architecture including collaborative learning, middleware, and personalized learning. IoLT also considers a number of technological aspects including IoT-cloud integration, data management, content delivery networks, wireless connectivity, and security. Another platform that enables students to create WSN networks using the MQTT application protocol in different IoT setups was presented in [5]. It was based on the integration with the LabVIEW software and a set of compatible devices. In [6], an IoT prototyping platform that provides single laboratory workbench of modular hardware architecture was proposed. It enables students to master the development of IoT prototypes using a set of hardware modules. The system was also integrated with the Node-Red platform and The Things Network (TTN) cloud platform for facilitating IoT application development. A similar prototyping platform was also implemented at the University of West Bohemia in Pilsen as presented in [7]. The focus was on prototyping and validation of low-power wireless IoT devices and technologies. On the other hand, reconfigurable and flexible IoT prototyping platforms were presented in [8] and [9] to practically introduce the development process of robotic-based IoT systems. Moreover, a Remote Virtual Experiment and Simulation Platform was proposed in [10] for IoT Related Courses. It enables students to experiment certain IoT concepts and allows teachers to monitor and evaluate students works anywhere anytime via the Internet.

There are a number of educational IoT platforms that consider educating the different IoT aspects. For most of these, the target was to make a simple educational environment for novices who needs easy and clear to understand way of education. As being a new technology, we have envisaged the importance of developing an IoT educational platform for the College of Computer at Qassim University. The main focus is to build the system that will help students and novices to learn the basics of IoT in an interactive manner. It also gives a chance to propagate the IoT knowledge for the public, especially for the kids and young people.

3. System Requirements Analysis

The interdisciplinary nature of IoT is a challenging aspect to different kinds of novice IoT learners at different ages. For example, the need for distinct networking requirements such as low power and lightweight processing introduced new networking models for IoT. The need for gateway connectivity, cloud management, and data processing also make it a complex field to comprehend. For novice learners, it is evident that there is a need for simple and easy-to-access educational environment to learn IoT. Using conventional education methods would make the teaching-learning process of IoT become more challenging. Educators needs to improve different practical skills of students to facilitate IoT applications and services development considering the plethora of diverse computing concepts. Students require motivating educational environment that effectively enables acquiring knowledge through hands-on and interactive systems. Therefore, the design of the IoT educational platform should factor in different characteristics including simplicity, practicality, usability, interactivity, and efficiency in presenting the different aspects of IoT.

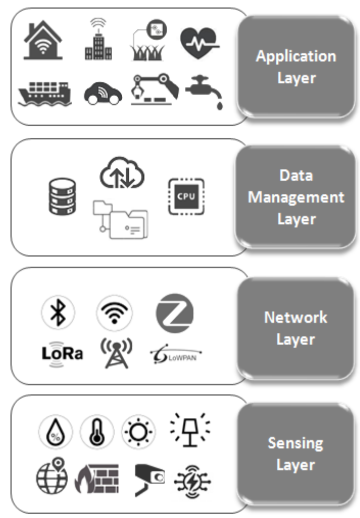

Fig. 2 IoT Architecture.

IoT architecture is composed of several layers as shown in Fig 2. The design of the system should incorporate these layers in a flexible and modular manner. It also needs to facilitate flexible configuration for each layer. The sensing layer includes the sensor devices that capture sensory data from surrounding environments. The network layer incorporates the use of IoT communication technology for interconnecting sensor devices in a wired/wireless sensor network and to the Internet. The data management layer integrates IoT systems to the cloud for IoT data sharing and management. The application layer involves the use and processing of the collected IoT data to establish a specific IoT application.

According to [11], IoT courses can be classified into four categories as follows:

- A single course introducing IoT Concepts;
- A course involving IoT Concepts;
- A focused course as part of an IoT specialization;
- A course focusing on certain IoT Use-Cases.

The proposed system is intended for novice learners of IoT and needs to provide a simple educational platform that facilitates simple introduction to the IoT technology. Therefore, the focus in this work is on supporting the first category which considers simple introduction to different IoT concepts.

Essential system requirements would also include effective control of the system and the ability to easily reconfigure its functionality. Moreover, accessibility to the platform should be effectively managed and made easy for the different kinds of potential users. It is also important to feature remote and online access to the system. Students should be able to interact with the system in a simple and clear manner. For example, the system should enable students to easily establish network connectivity among multiple sensor nodes, communicate sensor data with the cloud, and build a simple IoT application. On the other hand, the design should be secured enough to ensure no unauthenticated access and unauthorized use of the system.
Additionally, the system needs to fulfill a set of non-functional requirements including:

- Scalability: It is important to build a scalable system that can be expanded at the software and hardware levels.
- Portability: The system should be flexibly portable and developed to be conveniently carried to and deployed in the educational area.
- Flexibility: The system should be flexible to meet the different requirements of the current and potential users.
- Cost-effectiveness: The cost of building the system needs to be maintained at the minimum without sacrificing its main functionality.
- Management: effective management of the system is critical at both the hardware and software levels.

4. System Design

The design of the platform has been realized using a collection of architectural components. Fig 3 provides an overview of the platform design. We can see that the system design is based on a number of hardware and software components. It has been carefully established to ensure a modular, scalable, and cost-effective system.

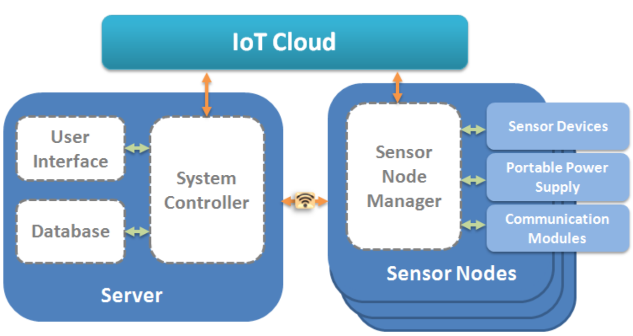

Fig. 3 System Design Overview

4.1 Hardware Components

The hardware components of the system are composed of two main parts. One is the server which represents the control unit of the system and the web server for the users. The other is a set of sensor nodes connected to the server over a control network using wireless connectivity. Each sensor node has a number of attached sensor devices such as the temperature, humidity, pressure, light, gas, dust, barometer, flame, luminance, water, and loudness sensors. In addition, communication modules are also connected to operate certain wireless IoT communication technologies such as Zigbee, Lora, and Bluetooth Low Energy. Each sensor node is also connected to a portable power supply. The server and sensor nodes need to be connected to the Internet using permanent WiFi connections.

4.2 Software Components

The server and sensor nodes are composed of a set of software components designed in a modular fashion. The server runs different software modules including the controller, user interface, and database. Each sensor node has sensor node manager, communication, and sensor software modules:

- Controller: The Controller provides central control and management for the system. It controls access to and operations of each of the nodes. It helps having a full control on the system and allows users to connect with each part of the system.
- User interface: The user interface provides a display for all the system materials and enables easy access to the system resources. For effective accessibility, it is designed as a web-based interface that is connected to a web server.
- User Database: The server has a simple database designed to hold user data.
- Sensor Node Manager (SNM): SNM is the control software for the sensor nodes. It receives requests from the controller to perform certain operations. These may include turning on a communication module, starting sensor reading, and sending IoT data.
- Communication Module: This is the software module that is responsible for establishing wireless IoT communication with other sensor nodes using the built-in and attached communication devices.
- Sensor Module: Each sensor node has a software module for controlling the attached sensor devices.
- Energy Monitoring Module: Each sensor node has a software module for monitoring power consumption and the remaining energy.

Other software modules would include the module operating the gateway functionality for any established IoT network. It enables running the gateway functionality at one node and presenting how it works. Another important module is the cloud module which runs for both the server and each sensor node. It is responsible for establishing data communication with selected cloud platforms.

4.3 Basic IoT Topics

At this stage, the focus will be on presenting basic IoT topics for novice IoT learners. These topics are selected to provide very simple introduction to IoT and open the doors to the different concepts underlying the IoT technology. However, the system is flexible and scalable enough to add additional topics for further educational level. The selected topics are as follows:

- IoT Networking: there are many important basic concepts to which students need to be introduced to understand networking and data communication for IoT. These would include wireless sensor network architecture and IoT communication protocols.
- IoT and Cloud Integration: integrating IoT systems with cloud is yet another important topic that is introduced to the student in this platform. It helps explaining how the IoT system can be integrated with a cloud service and understanding IoT data collection, storage, management, and visualization.
- IoT Applications: the establishment of IoT applications can be for different purposes such as monitoring, control, or automation. Students are introduced to some basic applications such environmental monitoring.

4.4 User Interface

The system is designed to be easily accessible via a web user interface which has all the required materials ready to present the IoT topics in an interactive manner. Each of the topics is presented in the user interface using one or more separated web-pages. Each web-page includes the following:

- Interactive text and multimedia contents that are made ready for the explanation of the different IoT concepts considered at this stage.
- Practical demonstration of each presented IoT topic using one or more preconfigured scenarios. Each scenario is run using the hardware and software components of the platform and according to certain configurations set by the instructors.
- A Scenario Representational Display for displaying a representation of the currently running scenario. It presents the interactivity among the different underlying hardware components of the system and how IoT data is communicated among them during the running scenario.

The user interface is designed as the system front-end via which users can access the system in an interactive and simple way. Users can select among the different IoT topics presented in the home page of the system. For each selection, the corresponding materials are displayed on the user interface. In addition, the users can start the relevant scenario after entering the required configurations. Once running, the user interface interacts with the system controller which then sends requests to the sensors nodes for running the selected scenario.

4.5 Experimental Scenarios

Each of the IoT topics in this platform is practically represented in one or more preconfigured scenarios. Each scenario requires the interaction among the controller and sensor nodes. The controller is designed to establish a server-client connection with each node of the system. Once a scenario is called, the controller sends a request to the relevant nodes to run the scenario. Each node has a configuration profile for each considered scenario. Each profile is associated with some or all the hardware resources of the node. For example, one profile could indicate running the temperature sensor and sending the sensor data to the cloud using the WiFi connection or to another sensor node via a communication module.

Upon receiving a request, the SNM at the node discovers the selected scenario and runs it according to the configuration information set by the user. This includes the duration of running the scenario and the interval for reading and/or sending the sensor data. For example, a request may indicate that the scenario should run for 3 minute to sense motions every 5 second using a motion sensor in addition to sending the sensor data to the cloud.

At the Scenario Representational Display in the user interface, ongoing operations at the underlying system are represented for the students in real-time manner. For this to work, each node needs to communicate back with the controller and acknowledge every operation during the running scenario. The Scenario Representational Display is divided into different display parts. One part indicates the selected scenario and current configurations and node status. Another part shows the operating nodes and their configured topology, and represents any changes meanwhile. There is also a display for the current operation at each node and representation of data interaction among the nodes. This provides instructors with both the Scenario Representational Display and hardware components to practically explain the considered IoT topics in an interactive style.

4.6 Application Establishment Environment

The platform also provides a very simple Application Establishment Environment for building some basic IoT applications. This facility enables students to master building very simple IoT applications in an interactive manner. To create a certain IoT application scenario, rules need to be established first using varying selections including activate selected sensors, set certain events, and enable some actions. Specific configurations such as sensor reading interval and duration can also be configured to run a scenario. The created scenario is initiated by the students from the user interface and the controller sends a corresponding request to the nodes to run the scenario. The nodes keep replying the controller with all the information to display ongoing operations on the Scenario Representational Display of the user interface in a real-time manner.

5. System Implementation

The implementation of the platform was based on selected hardware components and the development of a set of software modules. This section provides a thorough description of the current implementation of the system. Fig 4 shows a representational overview of platform implementation.

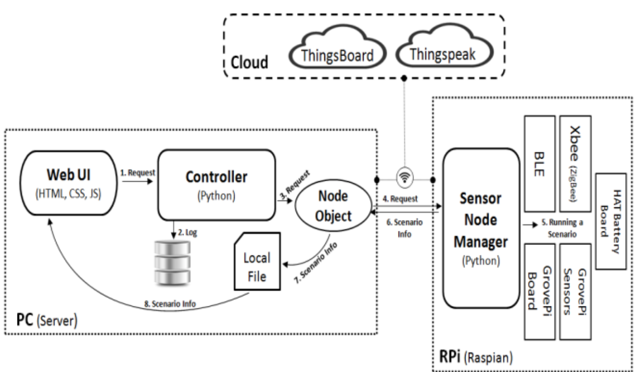

Fig. 4 System Implementation Overview.

5.1 Hardware Implementation Overview

The platform implementation is based on a set of open-source hardware components as presented in Fig 4. A PC laptop was used as the server of the system, with Intel Core i7 processor, 16 GB RAM, and 500GB hard disk. A set of Raspberry Pi devices (Raspberry Pi Version 3 Model B) was implemented as the sensor nodes. Currently, the system contains 3 sensor nodes in order to make it effectively portable, but the number can be expanded flexibly. They run Raspian which is stable, free, and open source Linux-like operating system. Each Raspberry Pi device provides good processing power, storage capability, built-in WiFi and Bluetooth modules, and a wired Ethernet port. It can also be expanded with a variety of external sensors and communication modules. In the current implementation, additional set of modules are connected to each Raspberry Pi device as follows:

- XBee S2C ZigBee device (from Digi International) supporting ZigBee communication. It is connected to one of the USB ports of the Raspberry Pi device over a serial connection.
- GrovePi+ Sensor Board (from Dexter Industries) providing simple sensor attachment. It is connected to the GPIO pins of the Raspberry Pi device.
- Collection of compatible sensor devices connected to the GrovePi+ Sensor Board. These include temperature, humidity, barometer, dust, air quality, gas, light, sound, motion sensors, in addition to a set of LED modules of different colors and a buzzer.
- UPS HAT Battery Adapter Power Supply Extension Board for powering the sensor nodes and having battery-powered node implementation.

Each of the server and RPi has a WiFi module. It was used to establish a control network among the server and RPi devices over a private access point which also provides access the Internet. Each RPi also has a built-in Bluetooth Low Energy (BLE) module that was utilized to establish IoT communication in one scenario as explained later.

5.2 Software Implementation Overview

A functional implementation of the main software components of the system was developed over the system hardware architecture. As presented in Fig 4, different software development tools was considered as follows:

- The user interface was implemented as a web-based interface using a collection of tools. HTML, CSS, and JavaScript were utilized for the development of the system front-end and to build interactive web-pages for the user interface.
- The database was created with simple implementation using PostgreSQL to store users and students data including mobile number and email address.
- The different functionalities of the controller and sensor node manager were implemented using

Python.

- The communication, sensor, and battery modules for each sensor node was also developed using open-source Python classes.

The current implementation of the user interface incorporates a set of functionalities. These include handling user input and initiating a request for running a selected scenario. This was implemented using a web socket established with the controller. Once received, the request is handled by the controller to be firstly logged in the database as depicted in Fig 4. Each request indicates the selected scenario and user configurations including scenario duration and sensor data reading/sending interval. Then, it is forwarded to each of the sensor nodes via an IP socket. This is achieved using a threaded object created for each sensor node. After receiving the request, the sensor nodes run the selected scenario for the selected duration. At every interval, the sensor nodes reply the controller with the required data to insure real-time display of the ongoing scenario information and visualization of the collected IoT data. These replies are received by the node objects at the controller to be then written to local files. A JavaScript function was implemented to access the files frequently and obtain the data for the display on the Scenario Representational Display of the user interface.

5.3 The Implemented Scenarios

The implemented scenarios are IoT communication using Zigbee and BLE, IoT-cloud integration with Thingspeak and Thingsboard, and environment and activity monitoring applications. The following is a brief implementation description of each scenario:

IoT communication using Zigbee and BLE:
The focus in this scenario is on presenting the main characteristics of IoT communication compared to WiFi. These include the transmission range, power consumption, and data rate. Users can select either running IoT communication using the attached Zigbee module or the built-in BLE module. Once running the scenario, a simple wireless sensor network is established among the sensor nodes. One sensor node is configured to run as a gateway (or a coordinator in the case of Zigbee). The others act as normal sensor nodes which read and send sensor data to the gateway at the configured interval. Upon receiving any data, the RSSI is obtained from the communication module and reported to the controller for real-time display. This scenario allows students to interact with the platform and move the sensor nodes apart to examine the capability of Zigbee and BLE in terms of transmission range. The transferred data can also be specified by the students, instead of obtaining sensor data, to examine the data transmission limitation of IoT communication. Another option is using the Python APIs to access the battery module attached to each RPi device and monitors its energy usage during ongoing communication. This is reported to the controller in order to present how much power is consumed for data transmission after completing the scenario. It enables understanding power consumption of the IoT communication over Zigbee and BLE at the end nodes and over WiFi at the gateway node. It is also possible to have a node sending data more often at high bit rate in order to understand the impact on the node lifetime.

Integration with Thingspeak and Thingsboard:
In this scenario, the sensor nodes read and send IoT data to the cloud. Then, the data can be obtained and visualized by the controller. The students can also access and process the data at the cloud platforms. The current implementation is integrated with two public cloud platforms, namely Thingspeak and Thingsboard. Each provides a python API that can be used to write and read data. An account was created at each cloud platform and configured to receive and store the sensor data from the sensor nodes. Once running the scenario, each sensor node reads sensor data from all the connected sensors and sends it to the cloud. Users can select to have the data sent to the Thingspeak platform for simple IoT data presentation or the Thingsboard platform for more advance IoT data management. After that, the sensor node informs the controller of each successful data transmission. The controller then obtains the data from the cloud to be visualized on the user interface. Students are also provided with access to the cloud platform for further data processing and visualizations. Each of the cloud platforms supports effective IoT data processing and visualization tools that can be utilized by the students.

Environment monitoring application:
This scenario introduces a simple IoT application for environmental monitoring. It is based on having one sensor node reading temperature, humidity, and pressure sensor data and the other reading dust and air quality sensor data. Once running the scenario, each sensor node reads and sends the sensor data to the gateway over the Zigbee connection at the configured interval. The data is forwarded to the controller once received at the gateway. At the controller, the node objects write the collected data to a local file. The data is then obtained by the JavaScript module for real-time display in a simple monitoring dashboard at the user interface.

Activity monitoring application:
This scenario presents how an IoT system can be developed for simple activity monitoring. The light intensity and sound loudness is sensed by one node while

the other senses motion in the same area. Once running the scenario, each sensor node reads and sends the sensor data to the gateway over the Zigbee connection at the configured interval. Once received at the gateway, the data is forwarded to the cloud for real-time display and data visualization. In case there is any reading above a configurable threshold (indicating a suspicious activity), an alarm is sent to the controller for real-time display. In addition, an alarm SMS and email messages are sent to the students' mobile numbers and email addresses, respectively, as obtained from the database. Students can interact with the platform to examine the system functionality by experimentally triggering certain alarm.

5.4 Implementation of Application Establishment Environment

In addition, a simple implementation of the application establishment environment was developed with a front-end and back-end implementation as presented in Fig 5. The environment can be accessed in a separate web-page with a collection of objects from which students can select to build different IoT application scenarios. These objects are organized into different sections including sensor node, sensors types, events, and actions. To create a rule, students firstly need to select the type of the activated sensor for a sensor node. In this implementation, the available sensors are temperature, air quality, gas, light, sound, and motion. The second section enables setting a specific event for the selected sensor. The available options are high and low threshold which needs to be entered as a number. Then, the event is associated with a certain action which can be turning on a colored LED or a buzzer and sending an alarm message. After creating the required rules, the scenario settings including sensor reading interval and scenario duration needs to be specified before running the scenario.

After that, all the details of the created scenario are written to a local configuration file. The controller then accesses the file for getting the scenario information and logging it in the database. It then sends a request indicating the selected sensors and user configurations to each sensor node. An Application Class was created for the sensor nodes with all the required processes to handle and run the requested scenario. A new object is created for each request to runs the relevant processes for getting readings from the selected sensors at the configured interval. The sensor data is sent back to the controller for real-time display. The sensor nodes also apply the selected events and check every sensor reading against the corresponding configured threshold. In case there is an action that needs to be taken, the controller is signaled accordingly. If the selected action is LED coloring, the sensor node runs the relevant process for duration of 30 seconds. Otherwise, the controller displays an alarm message on the user interface and sends alarm SMS messages to the mobile number of the student running the application scenario.

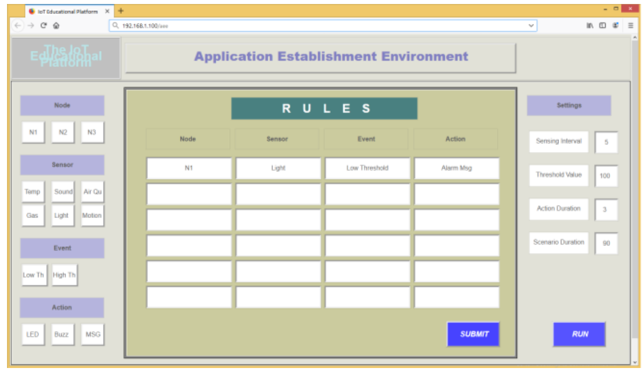

Fig. 5 The Application Establishment Environment.

6. Usage Example

The current implementation of the IoT educational platform can be used to introduce different IoT concepts in a simple and interactive manner. One interesting use case is demonstrating Zigbee communication in a multihop network setup. The IoT communication scenario using Zigbee was initially used to establish a single-hop wireless sensor network with one gateway and the two end nodes connecting to it. Students then interact with the platform and move the end nodes apart until one node becomes far enough to be only connected to the other one which should stay connected to the gateway. The interconnectivity among the sensor nodes was visually represented in the Scenario Representational Display of the user interface for the students to monitor ongoing operations and connectivity status among the sensor nodes. During this process, continuous data transmission to the gateway was configured to examine the effect of the change in the network setup. Moreover, the energy consumption information reported periodically for every data transmission was utilized by the students to understand the impact of multihop communication on network lifetime.

Another use case was using the application establishment environment to build a smart home scenario for home safety application. One node was selected to read data from the motion and sound sensors while the other reads from the gas and air quality sensors data every 5 seconds for the duration of 4 minutes. The selected event was to detect any reading higher than a threshold configured by the students for each sensor. For the action to be taken, we selected sending an alarm SMS in addition to turning on the red-colored LED and the buzzer for 30 seconds. Students temporarily stuck the first sensor node above the classroom's door while the other to the ceiling. When the scenario was running, the events were experimentally generated to examine the created application.

7. Evaluation

For effective evaluation, the proposed platform was used in two introductory courses to the IoT technology in a normal classroom. A total of 38 participants attended the courses and utilized the different functionalities of the platform. The ages of the participants ranged from 18 to 42, and most of them had some technical knowledge with no IoT experience while few had some IoT knowledge. The evaluation was based on the observation of the participants while using the system. Every participant has a smart phone, tablet, or laptop to access the platform. Participants also filled a questionnaire after the course.

The evaluation questionnaire was developed following the Technology Acceptance Model (TAM) [12] which is a commonly used approach to analyze technology usage behavior. The questionnaire was structured with four TAM factors to measure 12 items in a rating scale. The considered factors are: Perceived Usefulness, Perceived Ease of Use, Attitude toward Usage, and Behavioral Intention to Use. The questionnaire was based on a 5-point rating scale ranging from "1: strongly disagree" to "5: strongly agree". Fig 6 presents the TAM of the Platform.

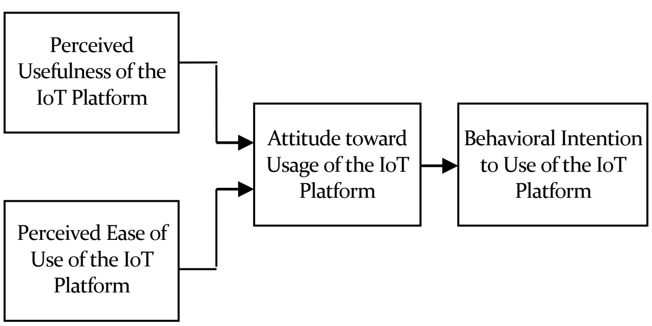

Fig. 6 The TAM Model of the IoT Educational Platform.

The evaluation data were collected and analyzed to firstly assess the reliability of the results. For this, the Cronbach's alpha coefficient was calculated for each TAM factor. As presented in Table 1, each factor has a coefficient value greater than 0.7 which is the minimum acceptable value. Table 2 shows the overall results of the evaluation questionnaire. It presents the calculated scoring average and the statistical standard deviation for each factor. As the results indicated, the students agreed that the platform is useful and easy-to-use for introducing the IoT technology. The results also showed that the students had a positive attitude toward the platform and good intention to use the system in future.

Table 1: Cronbach's Alpha Coefficient Results

Factor	Cronbach's Alpha Coefficient
Perceived Usefulness	0.832
Perceived Ease of Use	0.879
Attitude toward Usage	0.922
Behavioral Intention to Use	0.859

Table 2: Average Scoring Results

Factor	Average	SD
Perceived Usefulness	4.36	0.69
Perceived Ease of Use	4.29	0.67
Attitude toward Usage	4.17	0.73
Behavioral Intention to Use	4.22	0.80

Table 3: Relationships among TAM Factors

Independent Factor	Dependant Factor	PC	R^2
Perceived Usefulness	Attitude toward Usage	0.775	0.60
Perceived Ease of Use	Attitude toward Usage	0.811	0.65
Attitude toward Usage	Intention to Use	0.842	0.71

In addition, the Pearson Correlation was calculated to measure the correlation between the factors. It is an important statistical measure to understand the dependency relationship among the TAM factors. Table 3 presents the results of the factors correlation in addition to the R-Square calculations which determine the variance of the independent factors. It can be noticed that the Perceived Usefulness and Ease of Use are positively correlated with Attitude toward Usage. This indicates that students tend to use the platform as they found it an intuitive and useful system for understanding the IoT technology. There is also a positive correlation between the Attitude toward Usage and Intention to Use. The results clearly indicate that the students were satisfied with the system and willing to use it.

8. Conclusion

An effective IoT educational platform that takes IoT introductory courses to another level of practicality and interactivity was presented in this paper. The platform provides a motivating educational environment for effective and collaborative IoT learning. It enables educators to introduce the IoT technology with practical demonstration of the different IoT concepts. Using the different functionalities of the system, students can apply acquired knowledge to practice the development of different IoT applications and run certain IoT experimental scenarios. The design of the platform provides a usable, scalable, portable, and flexible system. Learning and demonstrating the basic IoT topics was made inspiring in simple and practical system design architecture. Effective implementation of the platform was developed using a set of cost-effective hardware and software components. The evaluation results show that the usability and usefulness of the platform for introducing the IoT technology and learning IoT basic concepts. The platform received positive attitude toward using the system for practical and interactive IoT education. The platform was also found to be effective for future use in introductory IoT courses. Given the modularity and flexibility of the platform design, the platform can be extended to target advance IoT courses in future stages. This includes the support of additional IoT wireless technologies such as 6LowPAN for IP-based networking and LoRaWAN for long-range communication. In addition, a set of user APIs will be developed to facilitate effective practice of IoT programming. The platform is intended to support further IoT prototyping for practicing the development of advance IoT application scenarios such as smart home automation. This will also be supported with the integration of a number of machine learning algorithms to teach advance processing and analysis of IoT data.

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