Internet of Things Simulation Tools: Proposing Educational Components

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***Abstract*— Internet of Things (IoT) refers to a developing and prevalent trend which provides connectivity between a huge number of objects (things) by using innovative features of the Radio Frequency Identification and Wireless Sensor networks technologies. As IoT develops, it is being expanded in magnitude and scope, reshaping the context of human life. Education is one of the most popular areas in our life where IoT can have an influence on. The educational process can be implemented and tracked by making use of the IoT objects and devices. In this work, an educational component is proposed in order to include it in the IoT simulation toolkits. A four-block module containing educative objects is designed and proposed. The module includes the smart elements, such as smart backpack, IoT school check in, smart desk and whiteboard. The final model design includes the procedures, methodology, block design and functions of each element. The paper shows that the IoT educational components can provide a novel and flexible virtual platform which can take advantage of the IoT features in the learning system.**

Keywords-Internet of Things(IoT); Smart desk; Smart book; Educational components;Web of Things(WoT);Smart objects; Smart whiteboards; Smart backpack.

I. INTRODUCTION

The basic idea of Internet of Things (IoT) is a new model based on the presence of a variety of objects like Radio Frequency Identification (RFID) tags, sensors and actuators that are able to interact with each other [1]. Internet of Things is considered the internetworking of smart physical objects that are enabled to collect and exchange data through the unique IPv6 addressing schemes. Also, it refers to the use of smartly connected objects, agent and devices to manage data obtained by embedded sensors in the machines and other physical-virtual objects. Based on the recommendation of The Global Standards Initiative on the Internet of Things (IoT-GSI) [7], IoT has been defined as the global infrastructure for the information society that can facilitate the interconnecting of the physical and virtual things based on the RFID and Wireless Sensor Network technologies. IoT-GSI also emphasized on establishing a Study Group on IoT and its applications, in order to promote an integrated methodology for the development of technical standards related to the IoT objects [2] [3] [4] [5].

The range of IoT applications (few applications are currently developed [6]) and the driving technologies, are expanded form the smart-cities to the complex IoT systems. IoT applications can embrace all human-object activities such as the smart home & cities, online-business, smart environment, security & emergencies, smart transportation, smart energy consumption, smart industrial process and education.

More than 50 billion sensor devices will be connected through the Internet by 2020 and a huge number of users will interact with each other over the many smart areas in different forms of the services, programs or applications. [14]. IoT devices provide connectivity for the objects, and systems, Machine-to-Machine (M2M), machine to object and object to object that implies a complex topology between devices. It means that it is required to design the objects with specific feature and capacity such as a small processor, memory, radio and software [9] [10]. The implementing of a complex topology for interconnecting between large numbers of devices is not simple to design. In these cases, simulation of the functions is required to study the scenarios before implementing them. In addition, the connectivity between objects is affected by their geographical features such as the location, their capabilities, and quality of the communications [13].

The huge number of smart IoT objects are deployed over the sensor field and can be controlled remotely through the Internet. But, sometimes implementation of the IoT infrastructure is complicated to administrate due to inaccessible distribution fields such as volcano, wild jungle or even underwater deployment places [11] [12]. Based on the mentioned reasons, simulating the process and functions for IoT scenarios is required.

Simulating the events, functions, and platforms allows the designers to survey a problem at different levels of abstraction. This approach at a higher level of abstraction permits the developers to better understand the object interactions within a complex topology [15].

The IoT implementation field is a large space complex system and it contains lots of objects. Testing the applications running on the high density of physical objects is possible just by using a flexible platform in the labs. On the other hand, real implementation of an IoT scenario is challenging since complex IoT environments are dynamic. Hence, simulation modeling of the IoT scenarios is a proper answer to this paradigm [16].

This paper is organized as follows: after giving a brief description around the main topic, a state of the art related to the previous IoT simulation studies is explored in the second section. The third section broadly discusses the case study model of the proposed components along with the IoT basic system architecture, technologies that support IoT and main blocks of the system design. Finally, a concise conclusion and future work will be described in the fourth section.

II. Related Work

In order to provide smart services, modeling of the IoT environments is a big challenge due to the existing difficulties in designing heterogeneous environments, nodes, devices and wireless technologies [13]. On the other side, monitoring an event without the central administration is another challenge for identifying, observing the events and detecting the critical system components in time [17]. For these reasons, currently, in the real-time heterogeneous IoT environments, there exist very limited models and simulators. For example, Moschakis and H. Karatza [18] offer several simulation concepts for IoT environments. Sotiriadis et al. in [19] present a SimIoT derivative version of Sim-IC framework. SimIoT introduces an innovative level of security for IoT connected devices along with a very deep vision of the IoT behavior structure [20]. A fault model for dynamic IoT system is introduced by Ivanovitch Silva et al. in [21] with a novel perspective. Khan and Manate [22] [23] introduce an innovative infrastructure and coordination techniques for the large scale IoT infrastructure. MicroGrid [24] elaborates a platform for the basic simulation experiments, performing in the grid positions. DGSim [25] also provides a particular framework for scheduler implementation of various grid resource management in a simulation architecture. Finally, Belli et al. [26] present a Web of Things testbed tool. They claim WoT enables developers to design and evaluate easily, smart services and applications in a real IoT- environment.

Currently, IoT concepts and designs, as well as the communication technology, are involved in almost all human-machine activities. In fact, IoT comprises all macro human/object activities; among them, education is one of the most visible applications that IoT can be involved in. Also, it can be said that education is one of the most perceptible undertakings in the human life and is facing several challenges of technology development [8][27]. Simulation of the educational process implemented by IoT technology is one of these challenges. However, there exist several general-purpose IoT simulators such as Cisco packet tracer (recently added the IoT features) which can be used in simulating IoT process with the educational purposes [28]. But, in the most of IoT simulators, educative objects are not present.

The main idea in this work is to propose a novel model design related to the educational components in order to give a proper awareness to the designers with the purpose of incorporating IoT elements into the simulators. A basic model of the educational IoT component will be presented in the following section.

III. Case Study model

In this section, firstly, a basic IoT structure will be described as well as technologies such as Radio Frequency Identification (RFID) and Wireless Sensor networks (WSNs) that support IoT. In the second step, an IoT scenario will be discussed with a concise explanation of the proposed model.

A. The IoT Basic system Architecture

The most common basic IoT system architecture is shown in Figure 1. Based on Figure 1, a basic IoT architecture is divided into three layers. They are application, network and perception layers [29].

1) *The application layer* is responsible for providing smart services to the users through an interface.

2) *The network layer* is responsible for providing communication between the network devices and objects, cabling, clouding system, and a data local processing unit.
A gateway connection point is in charge of obtaining the information which are sensed by sensors of the perception layer.

3) *The perception layer* includes the physical sensors, objects or actuators.

A small sensor processing system includes the event sensing, local storing, data and controllers. These units build the perception layer.

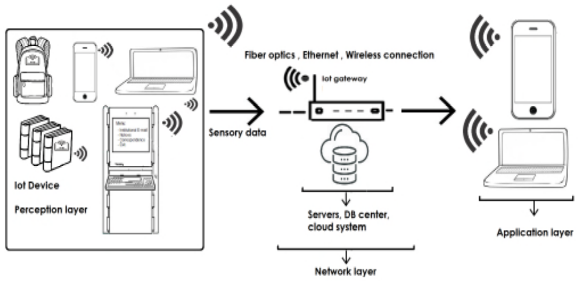

Figure 1. A simple architecture of IoT scenario

B. Technologies that drive IoT

1) RFID Sensor System

Figure 2 shows a basic RFID system architecture. The RFID readers detect the sensory data or receive the energy from the tag-pasted object and send information to a private cloud system for more processing or decision taking.

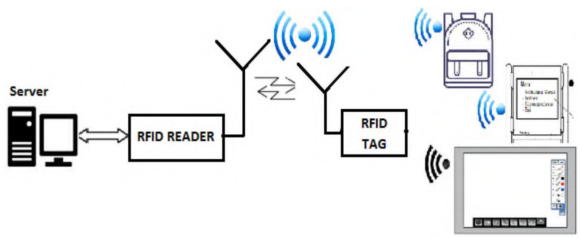

Figure 2. Block diagram of a typical RFID system

2) Wireless Sensor Network

As Figure 3 demonstrates, a group of tiny sensors distributed over a field can build a non-centralized network to sense an event and send the data back to a sink point (gateway) in order to monitor the area or further analysis related to the events [30].

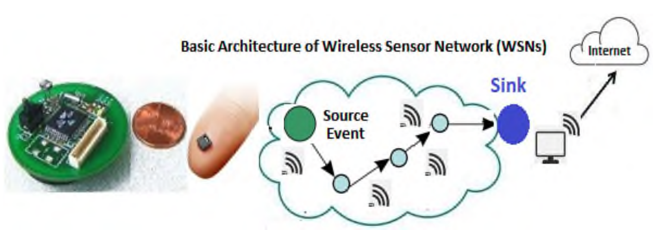

Figure 3. A Basic Wireless Sensor Network Structure

C. The Main blocks of the Module

The main blocks of the proposed model are shown in Figure 4.

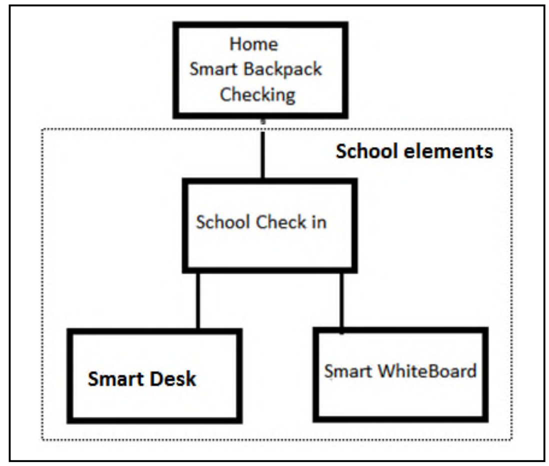

Figure 4. Main blocks of the proposed model

The proposed module consists of four separated blocks: Home smart backpack, school check in, smart desk and whiteboard. Based on the model, firstly, a pre-check of backpack content is carried out at home by students, parents or even a teacher. Mainly, this block is designed for schedule checking. After performing the pass-through authentication process, the user can check the diary agenda. The books or documents are RFID/WSN sensor labeled and will be identified when they are going inside or outside of the backpack. The movement of the RFID-labeled objects generates some control messages that will be sent through the IoT network to a smartphone or a display device for further analysis and collaborative actions.

Another component is the school check-in block that includes a two-phase IoT authentication process. This block is designed for getting access to the main school system menu by students or teachers. The menu for the students is different from the teachers. In this case, a user can have access to the personalized option designed for teaching or administrative objectives. The administrative menu is related to the managerial correspondences and functions, schedule of the semester, student list, etc.

Homework, exams, quizzes, projects, educational materials, evaluation results, and reports of the student will be available in the educational menu.

A second fingerprint authentication is employed for detecting the authority level of each user physically, in order to link the user to its educative profiles, correctly. The second physical authentication is used for user detection and connecting students to the options which are designed specifically for them, as well as their profiles. When the learners´ fingers touch the authentication device, the IoT system identifies if the user is registered in the database (DB) and the type of the user. The students can get access to the first level permission of the main menu designed for the learners. This menu contains many educative or (administrative) options for students such as: the actual semester program and enrolled courses, financial and scholarship status, smart homework, projects, smart exams, evaluation results, etc. The student users can touch any options of the menu and can find the personalized exam, quiz or any projects designed by instructors.

After passing the first checking level, the learners can look for the related class numbers that were registered in the main system. Last two blocks are related to the class activities. In a typical class, students have their own desks that sit on it. Each desk has a sensor for authentication (fingerprint or RFID card). So, each learner uses a smart unique desk and table. The desks are connected wirelessly or by a cable connection to the main IoT system. The smart desks can interact with other IoT devices through a gateway and a small private cloud system, sending or receiving the control messages. In the following, each component, its connections and functions will be analyzed in detail.

1) Home Smart backpack checking:

This component is related to the smart IoT backpack element. First of all, a RFID element and a WSN sensor is pasted on the backpack.

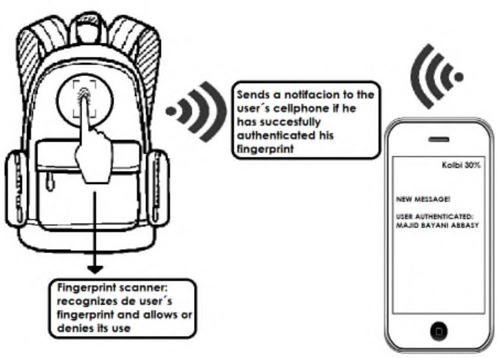

Figure 5. Backpack authentication

The process of authentication is performed through scanning the sensor (RFID or ID card) (Figure 5). This process is an essential security process to protect the unauthorized access to the smart backpack. As Figure 6 demonstrates, after checking the authorization the smart backpack is on ready mode and open status. The reader scans each object that goes into the backpack, sending the signal to the smart phone. The sensory data will be transferred through the IoT gateway to a private cloud system storing the information and control signals.

This element is designed as a flexible system that can scan all physical objects tracking, inside and outside of the backpack.

The sensory data are stored in a small cloud server, communicating with a display device such as a smartphone or a laptop through the internet informing the student parents or the same user. The users arrange this process based on their scheduling.

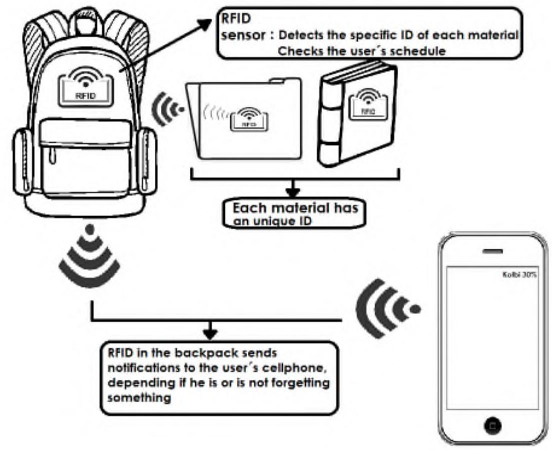

Figure 6. Backpack components

2) School check-in

Based on the main blocks topology, in the first phase of the school check-in, the people should authenticate themselves through presenting any physical identity such as the fingerprint, RFID card or the cellphone interaction with the central entrance terminal. Based on the registered information, the system can detect the validity or type of user. They can be a teacher, student or an administrative member of the institute.

Figures 7 and 8 show that after passing this phase, the user can get access to the personalized main menu. For example, if the user is a student, the options that appear on the screen will be available, exclusively, for the students. In the second phase, the student should perform the second IoT level of validity process. After verifying the user authority, once the user touches any option, more personalized functions for this particular user will be accessible. For example, if the user is a learner and touches the smart homework, a specific homework for this user, uniquely, will open to get access to that content. In this way, the users can have access to the several facilities by this terminal which is connected to school data base (DB).

Email notification is one of these facilities for both students and instructors. In this sub-option service, a web of thing (WoT) service provides the email service for the student and teacher users. They can observe a short list of the updated email box with related subjects and degree of urgency for future email checking.

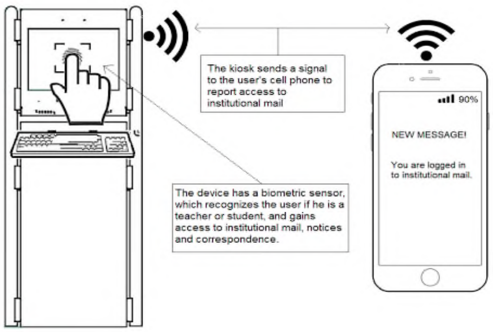

Figure 7. School check-in components

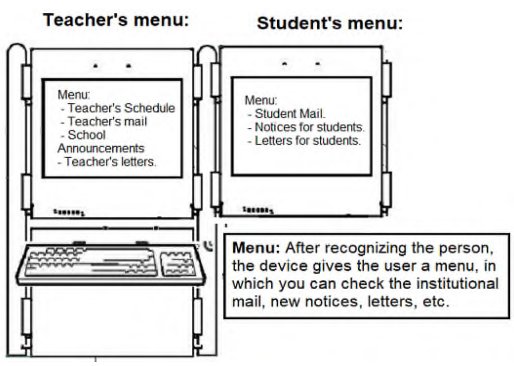

Figure 8. School check in second security level authentication

The third section is related to the smart desk component. The user can enter the smart class looking for preconfigured desks. The class is equipped with the smart IoT devices such as smart desk, smart board, etc.

3) Smart Desk

Each student has a preconfigured smart desk equipped with the IoT sensor detection. Figures 9 and 10 show a scenario in which the smart desks interact with the users.

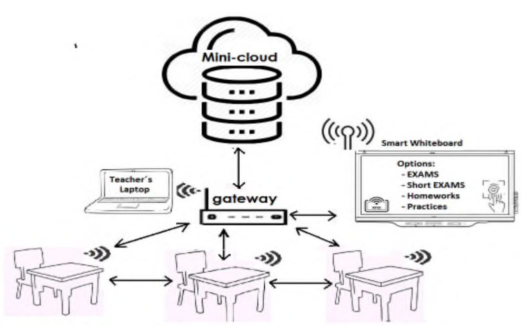

Figure 9. Smart Desks

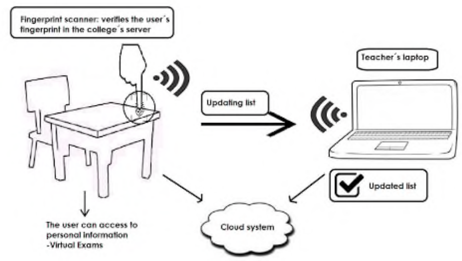

Figure 10. Smart Desk Authentication

Based on Figures 9 and 10, when the users pass the authentication process by checking fingerprint, RFID ID card or a cellphone interaction, they can use the facilities of the smart desks. IoT desks can connect to the network via wireless or cable connection. They can interact with the smart whiteboards as well as the teacher device. Once the users demonstrate the required authority, they can have access to the main system and offered services. For example, they can receive what the instructor is writing on the whiteboard and see it on their laptops. They can also interrupt the professor's lecture (configuration and permission needed) and write enquiries or questions.

The smart desks can be employed for attendance checking list in a secure method. This is an IoT secure way to send the list to a mini-cloud system. The professors can generate a report of the list by using the data stored in the cloud system.

As IoT can implement and use the WSNs, all WSN sensors will be activated and a mini monitoring system can track graphically the user nodes, in a real time mode.

The last component of the module is a smart IoT whiteboard that will be discussed in the following section.

4) Smart Whiteboard

This block contains the authentication IoT elements, and users can check the security validity, physically (Figure 11). A Web of thing (WoT) system software connected to the whiteboard collects the sensory data sending them to a private cloud system.

The users can have access to their personalized facilities built in the smart whiteboard. The educator can touch the menus and get access to the educational services that they need.

A menu with several options appears on the screen and users can select any option or service that needed to proceed. As the validity checking is a physical IoT process, different profiles for instructors can be defined in the main WoT system. For example, the professor of a particular course can get access to all packages related to that course. In this form, the IoT technology provides multi-discipline area platforms for different courses, purposes or users. Similarly, the student users can obtain and get the services after the validity check that is provided only for the students. They can interact with the whiteboard IoT system through their smartphones to send and receive the messages, questions, images, text, or even send an interrupting message during the instructor's lecturing.

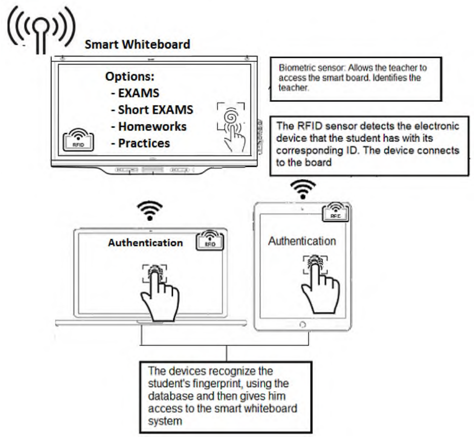

Figure 11. IoT smart Whiteborad components

Figure 11 is a graphical demonstration of a smart IoT whiteboard structure. Based on the Figure 11, the learners can interact with the whiteboard. The smart whiteboard has the capacity of dividing in several areas: student area, messaging, questions, and lecture areas. In this way, in a real time mode, the learners can exchange information with the teacher and vice versa. The instructor can receive the messages and queries from the students and answer them. The students can see the answers on their laptops or computers. Both students and teachers can validate physically their identities through a RFID ID-card taking advantage of the IoT authentication feature.

IV. CONCLUSION AND FUTURE WORK

Many times, implementing the complex procedures in a real mode is difficult and performing a process for the innovative phenomenon is converted into a big challenge. The solution for these cases is "simulating the process". IoT technology is involving in all aspects of the human life. It can provide a platform and many facilities in many areas such as in education. This paper presented a novel application of IoT, offering an *educational IoT module* with physical-machine object authentication. The main idea in this work is proposing the educational components for IoT simulation toolkits. These elements are smart backpack, IoT check-in system, and two more elements; smart desk and whiteboard that are practically used in the smart IoT class. In case of the smart backpack, the objects (books) will be WSN/RFID labeled which can facilitate a real-time monitoring of the object tracking. This system helps the parents (or the same user) to check the user's activities. The check-in school system is another IoT system that eliminates the web authentication process just by using a physical authentication. The user performs the check-in process before entering the classroom. The two-level physical security system increases safety of the system. The users based on their predefined profile can get access to their options. The second component is a smart desk. The users log in physically to have access to the services and interact with other objects such as a smart whiteboard. The idea of proposing this novel component is to inherit all benefits that IoT can provide for a typical education scenario. Internet of things can remove the physical existence limitation and increases the accessibility to several educational recourses and tools, anytime, anywhere improving the effect e-learning.

IoT and related technologies such as RFID and WSN can elaborate a flexible collaboration platform through connecting the objects. And also, it can offer a more secure system by eliminating the traditional web-based authentication process by using the physical authentication.

This work is considered as a first step to take to involve the IoT concepts in the educational objects. Connectivity, collaboration and scalability are some of the advantageous attributes of the IoT that are inherited by any IoT-based learning system. Based on this reality, our future work will be focused on implementing tangibly the proposed module in order to study the impact of applying an IoT-based structure on the learning system performance.

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