
International Journal of
Advancements
in Mathematics

Available Online
International Journal of Advancements in Mathematics
http://www.scienceimpactpub.com/IJAM

Energy Conservation Smart Classroom System using IOT

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Abstract

Numerous technologies, such as the Internet of Things, have significantly contributed to energy conservation in response to the increase in global energy consumption in many sectors, including industry, education, and transportation. This article explains how to set up an intelligent classroom system based on the Internet of Things that saves energy in the classroom. The proposed method estimates the energy consumption of an Internet of Things (IoT) device, a smart classroom, and the building using the proposed energy consumption and cost model in addition to providing real-time access to and control over IoT devices like lights, projectors, and air conditioning. Our system's effectiveness and benefits have been proven through real-world testing in a university classroom installed with computers. This paper discusses how the Internet of Things (IoT) can be used to develop a less expensive and energy-efficient device control system. Almost any electrical device can be operated using this method with little to no assistance from a person. When students are present in the classroom, an "IoT Based Energy Efficient Smart Classroom" system is intended to lessen the load on the power grid. The technology detects the presence of a person in a specific area and uses that information to control the operation of electrical devices (such as ON/OFF). The device can adjust to a person's immediate environment's temperature, humidity, and amount of light by using a Microsoft Kinect sensor. A DHT22 sensor and an LDR are connected to an Arduino AT Mega board to measure various environmental conditions. This system has sensors that can gather real-time information about the classroom environment. A web application is then updated using this data. The Node MCU IoT device sends all of its data to the host computer through the internet. Final testing of the system took place in a lab with four students and 80 test cases. Based on the statistics, the final prototype appears to be 98% accurate.

Keywords: Energy consumption; energy conservation; energy cost; Internet of Things (IoT); smart classroom

1-Introduction:

Both population expansion and technological development contribute to the world's continuous need for more energy. Most countries are doing in-depth research to develop alternative, renewable, and sustainable energy sources to address the increased demand for power. Developed countries have recognized the feasibility of renewable and sustainable energy sources, of which hydrogen and biofuel are just two examples. One of the essential elements for human survival is energy. All structures need electricity as a source of energy. Hence its cost needs to reflect this. All electric lights and equipment should be turned off when not in use. Inside, a motion detector or occupancy sensor would be pretty helpful. Inner data [1] has shown that the world's energy consumption is increasing. Consider how human energy use increased from roughly 10,000 TWh in 1990 to about 23,000 T TWH (or more than double) in 2020. (i.e., more than double). The amount of energy consumed is also rising. According to data from the ministry of environment, water, and agriculture, CEIC stated in [2], the quantity of power used is increasing. For instance, this amount was close to 115 Tw in 2000.On the other hand, the amount of energy consumed significantly rose, rising by 251% to around 289 TWH. High energy consumption is a problem in several industries, including manufacturing, transportation, and higher education. We need efficient and reducing energy-saving methods right away due to the alarming rate at which energy consumption is rising. Energy management is challenging since there are so many moving parts. Many different kinds of information must be sent right now. An intelligent solution would therefore use the Internet of Things and other reducing monitoring and transmission technologies. As a result, in a "smart" environment, comprehensive energy management plans can be implemented [3]. Based on the Internet of Things, an intelligent classroom system uses the MQTT protocol to automate digital equipment (MQTT). A user interface, middleware, and a few wireless nodes make up a system. These latter interact with the middleware through a network developed or made just for them. The MQTT Internet of Things protocol is utilized to establish the connection. A publish-subscribe communications architecture is built on the TCP/IP communications stack. Users can interact with the middleware of the system by using the interface. The user only needs to speak the command out loud for the system to understand it. Employing concealed instructions is a powerful technique for improving user engagement with middleware.

The contribution of this paper is as follows.

This paper contributes the efficient use of Internet of Things (IoT) to develop a less expensive and energy-efficient device control system. Almost any electrical device can be operated using this method with little to no assistance from a person. When students are present in the classroom, an "IoT Based Energy Efficient Smart Classroom" system is intended to lessen the load on the power grid. The technology detects the presence of a person in a specific area and uses that information to control the operation of electrical devices (such as ON/OFF). More efficient version of temperature and humidity sensor is used which is DHT22 sensor and an LDR are connected to an Arduino AT Mega board to measure various environmental conditions.in previous studies mostly DHT11 was used. This system has sensors that can gather real-time information about the classroom environment. A web application is then updated using this data. The Node MCU IoT device sends all of its data to the host computer through the internet. Final testing of the system took place in a lab with four students and 80 test cases. Based on the statistics, the final prototype appears to be 98% accurate by using our proposed method of energy conservation, it can be extended for following applications.

1.1- Smart Campus

1.2- Physical Environment and Smart Classrooms

Researchers have looked into the quality of lectures using a "smart classroom." Using sensors, we could gather information on variables such as background noise, the amount of CO2 in the room, the temperature, the humidity, the speakers' volume, and the lecturers' movements and voices. To evaluate the data, several classification techniques are used. The most important environmental factors that affect a speech's quality are carbon dioxide (CO2), temperature, humidity, and noise level. This study investigated how the classroom setting influenced students' capacity to pay attention to the lecture. The CO2, temperature, air pressure, humidity, noise, and even the lecturer's voice was measured using Internet of Things sensors. Students' ability to focus is strongly impacted by heat and moisture, carbon dioxide levels, and the mean absolute deviation of incoming noise. The authors look into how students' beliefs about the value of digital learning technology affect their drive, engagement, and academic achievement. In smart classrooms, there was a positive association between student engagement and learning outcomes, but not between student motivation or opinions of how well the technology worked and learning outcomes. The physical environment appeared necessary for learning, based on what students said about the temperature, number of seats, classroom location, chair design, and general atmosphere. The results show that students' learning experiences are much worse when seated in a conventional classroom but not when using ALC. A web survey of the Future Classroom Lab (FCL) was done by European School net; according to the source, FCLs included a variety of learning zones, such as interact, present, develop, investigate, create, and trade. These figures show that people value FCL's location. A unique approach to teaching financial accounting in the classroom is suggested in Reference [16]. An intelligent classroom can be described in five ways: through displays, controls, accessibility, real-time interaction, and testing. Environmental factors like air, sound, color, door, light, temperature, humidity, attendance, and monitoring are covered in the book

1.3- Technologies in Smart Classrooms

Software, ideas, and architectural designs have all been employed to solve problems in smart classrooms. A tele-education classroom with two advanced on-wall interactive boards was built using a multi-agent software architecture known as "The Open Agent Architecture (OAA)." The "Smart Platform" solves the inter-agent communication problem in del e-learning. Network Education Ware, a software-as-a-service solution created to overcome network bandwidth difficulties, was provided. The context structure can account for, among other things, the users' locations, times, activities, services, surroundings, and platforms for context-aware issues in distance education. We find a suggestion for a coordinated distance learning system called "Open Smart Classroom." To provide remote programmed control, file uploads, and the addition of new remote classrooms to a current real-time class, this system makes use of web service technologies. Academics have previously investigated significant technological elements of several sorts of smart classrooms. The most crucial aspects of a smart classroom, such as speech recognition, computer vision, software for remote students, an interactive media board, live video, and pervasive computing, are described in depth in Reference [24]. Numerous RFID technology applications exist, including electronic wallets, public transit, personnel tracking, and door locks. The authors of Reference [25] developed an intelligent classroom system using near-field communication, a type of RFID (NFC). The suggested approach enables students to participate in interactive activities in real-time while validating their attendance. The findings show that interactive elements boost students' interest in learning. Interactive whiteboards and boards are vital in modern "smart" classrooms. The results suggest that IWBT can be a proper teaching strategy in various situations. The benefits and drawbacks of IWBT are covered in further depth. Users may also become upset by technical difficulties and improper system configurations. Large projections enable teachers to keep an eye on the performance of the entire class and educate students on how to work well in small groups, according to citation [27]. This article looks at how classrooms with lots of technology and multimedia might help students learn. For students to present their work and cooperate, they must have access to wireless and shared displays in the classroom. Although using cameras and video recording equipment makes some teachers uncomfortable, these tools are necessary for online education, creating lecture materials, and sharing presentations in real-time and provide a list of typical IoT devices used in smart classrooms, including interactive whiteboards, tablets, and other mobile devices, 3-D printers, eBooks, student ID cards, temperature sensors, security cameras, electric lighting, attendance tracking systems, and wireless door locks. Reference also surveys the use of IoT in education. It asserts that hurdles to integrating IoT and education include cost, administration costs, security and privacy concerns, and consistent WiFi connections. The findings show that the students on the experimental team were more engaged, picked up information more quickly, and had higher expectations for what they needed to retain. The source outlines a system that uses deep learning and emotion detection to give classroom presenters immediate feedback so they can enhance the quality of their lectures. A great example is an idea in Reference [12] to use technology in the classroom creatively. But a lot of computational power is needed for the application to work. So, the backend of the app must use a trustworthy cloud service. [15] presents a framework for carrying out learning analytics initiatives in a virtual learning environment. Web Services based on the Simple Object Access Protocol allow the components to communicate (SOAP). Web services can be published, found, and used by agents. Smart classroom objects employ the middleware called Ambient Intelligence and Cloud Learning to change their behavior depending on where they are and what each learner needs. The [13] reference provides student identification, learning process monitoring, analytic task use, resource recommendation, student community location, concept reinforcement using augmented reality technology, learning performance prediction, and assessment of learning materials quality.

1.4- Context-Aware and Energy Saving

The main components of ambient intelligent computing are listed. These characteristics include being rooted, unique, adaptable, and proactive. Situational awareness, allowing users to participate at their own pace, equipping them with skills transferable to different circumstances, working in groups, and building knowledge collaboratively is essential elements of an intelligent learning environment. In Reference [55], the applications of GPS, position sensors, and RFID technology are covered in detail. [16] proposes a framework for applications in smart cities. The suggested structure divides the Internet of Things by placing a fog layer between the Internet of Things and the Cloud. Applications for the Internet of Things can be divided into three main groups: those that are IoT-based, those that combine IoT and smartphones, and those that are smartphone-based. The suggested system's three components—data gathering, data pretreatment, data processing, and data analytics—work together to handle the collected data. This paper examines two applications for smart classrooms based on Arduino [57]. Ultimately, developing a "Smart." classroom depends on students being aware of their environment. As a result, the suggested design would include several context-sensitive elements. Using five categories—generation, storage, infrastructure, facilities, and transportation Reference [18] investigates the many ways cities manage their energy use. The authors state that without changing the system's hardware architecture or structure, building management and administration can be enhanced to cut energy consumption by up to 30%. According to the authors, buildings should not simply consume energy without doing anything. They ought to be active parts of the power system instead. To decide what was best for cities, researchers described in Reference [59] created a hierarchical decision-making framework for managing energy in smart cities. According to the findings, the method recommended in Reference [59] can boost a city's energy efficiency on a tight budget and in the face of complicated challenges such as conflicting goals and needs, disjointed decision-making, and crosssubsystem optimization. Research on district-level energy systems and their difficulties is found in the references [60–62]. To address concerns with scalability and adaptation, the authors of Reference devised a multicommodity energy management system. They did this by employing techniques for decentralized resource allocation and load scheduling. The simulation results in Reference [60] show that the decentralized algorithm produced identical results to the centralized method. This illustrates that there is room for improvement in how locally produced energy is used. A decentralized system for supplying renewable energy to networked smart houses is shown in Reference [61]. The simulation results suggest that the strategy uses the chance to combine renewable energy sources. People can reduce their energy costs as a result. An energy management system can be used to establish a demand response-capable energy district. Computer models show that the suggested technique decreases the peak power in energy districts during the day and the reverse energy flow at night. Finding the best institutional or residential energy management practices has been the subject of numerous studies, including providing a decentralized optimization method for micro grid energy operation scheduling. The micro grid's users can control their loads and employ pooled energy storage and renewable energy generator. The findings show that by pooling energy storage, the suggested strategy can lower the cost of energy use. A centralized system was created to control a building's energy usage. On top of a Siemens commercial SCADA system, the entire platform was built. The SCADA system described, when used in modern constructions, permits the efficient operation of several methods. A predictive controller and a set-up communication link can be used to access the SCADA system. Based on simulations and experiments, the suggested platform aims to meet consumers' stated needs as fully as possible while adhering to energy-saving regulations. A method for scheduling electrical activity in an intelligent house with programmable appliances, storage devices, and energy providers is shown. Cost-cutting about energy is the goal. Energy is produced using recyclable materials.

Further, in section two of this paper related work has discussed, in section three the proposed system & it's related mechanism is elaborated, in section four the Energy Consumption and Cost Model is discussed, in section five Implementation and Experimental Evaluation is done and at the end conclusion of this paper sum up the presented work.

1- Related Work

Industries where IoT technology has been shown to save energy, include those in transportation, health, smart cities, and education [4–7]. Several researchers have used the Internet of Things to help healthcare institutions lower their energy usage. An IoT-based software-defined wireless body area network communication system is shown by Askari et al. In particular, the authors offer a two-tire technique for energy-efficient real-time Walsh Hadamard code interference reduction using NOMA scheduling. To address the problem of energy conservation in a smart city, other researchers are looking into how to use the Internet of Things technologies. An innovative approach to managing intelligent buildings is put forth by Metallidou et al. [9]. The ventilation system, the heating system, the air conditioning system, the domestic hot water (DHW) system, the electrical system, and the lighting system are just a few of the many subsystems that make up the management system. To ensure that Internet of Things devices follows European energy efficiency rules, each design uses a Wireless Sensor and Actuator Network to carry out several tasks. The energy-saving EPSSR is introduced by Nahar et al. [10]. Before turning on the lights, the authors advise adding an infrared sensor to check if a room is occupied. The lights are turned off when the timer hits zero. Starting at 10, the infrared detector counts down. Many experts are considering how the Internet of Things (IoT) could help schools save energy costs. A loT-based autonomous power control system for lecture halls that promotes energy conservation was shown by Gupta et al. [11]. The idea of installing sensors in classrooms to recognize when students are present and turn on the lights appropriately appeals to the writers particularly.Additionally, there are two ways to operate the system: manually, in which the user can turn devices on or off, and automatically, in which sensors make decisions. Martirano [12] presented a system for energy-efficient classroom lighting. The author suggests using sensors to monitor how many students are in a class and how much time is spent in it. Additionally, the author offers two separate ways to dim and switch on the lights and two ways to regulate each way—manually and automatically. Paudel et al. [13] provide an energy-saving context-aware architecture for schools. To control the timing of devices, the authors offer a convolutional 3D network (C3D) model that uses a Short-Term Long Memory (LSTM) model to predict classroom temperature and humidity based on categorized student activities (i.e., lights, air conditioners, heaters, etc.). A smart classroom that saves energy was shown by Mohamad et al. The smart classroom controls indoor and outdoor lights and a security system for the entrance. Diddeniya et al. [15] . are trying to cut design for an eco-friendly, Internet of Things-based innovative classroom system that runs on a smartphone app with a graphical user interface (GUI), and Wii is also provided. The authors suggest three different sensor types: I. A Microsoft Kinect sensor for determining which students are present. a Light Dependent Resistor (LDR) sensor tracks the amount of light in the surrounding area. To control the temperature and humidity in the classroom, use a Digital Humidity and Temperature (DHT22) sensor. Memos et al. have offered several innovative ideas for a smart classroom [16]. (RISC). A cloud-based Learning Management System (LMS), additional components, and data transmission application protocols make up the implementation technique (e.g., tactile devices, virtual reality devices, and other sensors). The smart classroom will offer a wide range of services, such as a virtual classroom, augmented and cognitive sensing, position, touch interaction, 3D design and modeling, and more. An intelligent classroom infrastructure based on the Internet of Things is suggested by Ani et al. in [17]. To better use lighting and fans, the authors develop a system for counting the number of students in a classroom using image processing. One camera divides it in half to establish whether the school is entire. Frame 1's lights and electronics must turn on if a student enters it. They should shut off if they reach frame 2. Osmotic IoT is used by Pacheco et al. [18] to show how to build a smart classroom. The authors describe a deep learning model, particularly for cameras detecting human presence. The four layers of the construction are as follows:

IoT layer that contains IoT devices and cameras,

Edge layer that contains IoT hubs and mobile devices,

(Fog Layer that contains IoT and Vision servers,

The Cloud layer contains Cloud data centers for computing the deep learning model.

An Internet of Things and cloud-connected innovative classroom system is presented by Banu et al. [19].

The Personal Digital Assistant layer

This layer includes smartphones, laptops, touchpads, etc

Internet of Things (IoT) layer,

This layer includes cameras, lights, sensors, air conditioners, etc.;

Networking and Storage Layer

This layer includes a cloud server, routers, switches, etc.;

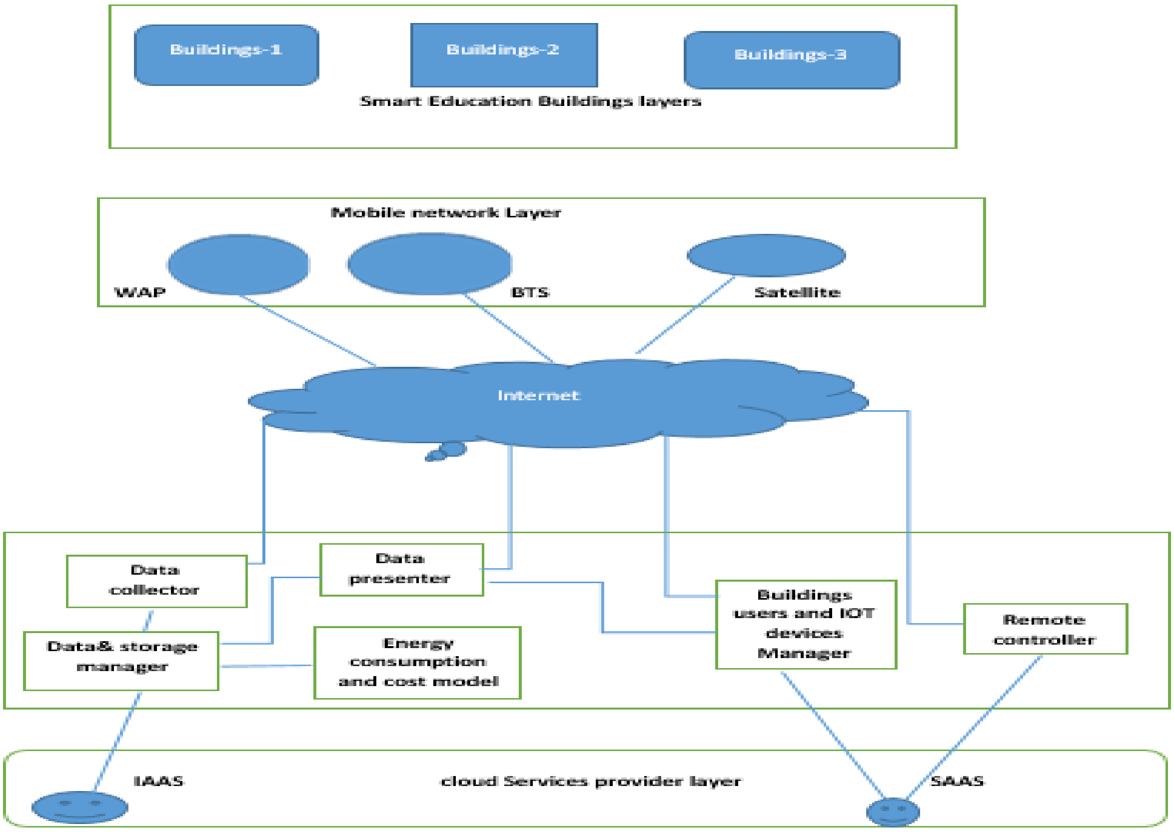
The Management Layer,

This layer includes supervisors, instructors, and students.

To track who is there, the suggested system also uses face recognition. The Internet of Things is used to power an intelligent classroom system covered in both Chan et al. [20] and Sun et al. [21,22]. A Wireless Sensor Network (WSN) energy-saving system that can regulate the temperature, lighting, and other environmental factors, as well as an RFID attendance system with an interface for the administrator and the teacher. We seek to apply IoT technologies to the field of education, as contrasted to the sectors of health and smart cities, where equivalent studies have previously been undertaken. This makes our research unique. Additionally, past research did not look into the viability of summing up the predicted energy use and anticipated energy costs of IoT devices in real time. This project creates a smart classroom energy-saving system based on the Internet of Things (IoT) that gives users real-time data on how much energy is being consumed and how much it will cost.

2- Proposed System:

We suggest an Internet of Things-based energy-saving brilliant classroom architecture that not only gives users real-time access to and control over Iot frameworks like lights, projectors, and air conditioning but also figures out the estimated energy consumption and costs of an IoT gadget, the smart classroom, and the entire building. Figure 1 shows the four architectural layers: Smart classroom management, mobile networks, brilliant educational facilities, and cloud service providers. The layers of Intelligent School Facilities comprise several intelligent schools, each with several interconnected classrooms. Every "smart classroom." has the Internet of Things devices in it. All IoT devices are under the Smart Classroom Management Layer's supervision, management, and application of the energy usage and cost model. d. Additionally, the F layer of smart educational buildings consists of a group of teachers who can monitor data about the energy usage and costs of the classroom and remotely control Internet of Things (IoT) devices in smart classrooms (i.e., by week, month, or year). The intelligent education buildings layer also consists of a team of building managers M, each of whom can: remotely turn on or off IoT devices in the thoughtful classroom; (ii) see which faculty member made the switch; (iii) view data about how much energy the IoT device, smart classroom, or smart building consumes and how much it costs; and (iv) add faculty members.



3.1- Mobile Network Layer.

This layer connects the infrastructure of intelligent schools with that of smart classrooms. Many Base Transceiver Stations (BTSs), satellites, and Wireless Access Points facilitate communication (WAPs). Data on how much energy is used by various IoT devices; administration of buildings, users, and IoT gadgets; identification of users; and requests to remotely power on or off different IoT gadgets are all examples of interactions.

3.2- Smart Classroom Management Layer.

These are the seven components that make up this layer: The I Remote Controller gives building managers M and faculty members F the ability to remotely turn on or off the Internet of Things devices and receive notifications when an IoT item is left on for longer than two hours by using a Software as a Service cloud service. The Buildings, Users, and IoT Devices Manager can assist the administrator with tasks like maintaining user accounts, adding the energy consumption rate for IoT devices, and adding buildings. The administrator is in charge of entering the energy consumption rate for the d th IoT device marked nd and the energy cost rate E (i.e., following SEC rates or the Electricity Tariff) as well as (iii) adding new smart education buildings to the system, managing users and IoT devices. The "Data Collector" is the last person on our list, and it is their responsibility to collate data regarding the Internet of Things' energy usage. (v) Data Management and Storage, which is in charge of managing and keeping track of IoT energy usage and cost data as well as providing access to their statistics, including the IoT device, smart classroom, or smart building (i.e., by week, month, or year), where it is stored in the Cloud datacenter via an Infrastructure as a Service cloud service. (vi) Data Presenter; this individual informs management and instructors of the building's energy usage and associated charges for Internet of Things gadgets. (vii) A model for calculating the cost and energy consumption of Internet of Things devices, intelligent classrooms, and buildings

3.3- Cloud **Services Provider Layer.**

Numerous cloud service providers in this level provide cloud data centers via IaaS cloud services for storing IoT energy consumption and cost data, as well as a SaaS cloud service for remotely turning on and off IoT devices and notifying associated users.

3- Energy Consumption and Cost Model

Building managers and faculty members can remotely turn on or off IoT devices and inquire about the energy consumption and cost of an IoT device, smart classroom, or intelligent education building in our suggested IoT-based energy conservation brilliant classroom architecture. The energy status of IoT devices is essentially a tuple representing a collection of Remote Controller history entries. Rh = (D, C, B, F, M, N r, S d, T d) where D is the ID for the IoT device, C is the ID for the smart classroom, B is the ID for the intelligent education building, F is the ID for the faculty member, and M is the ID for the building manager, Sd is the energy status of the IoT device, and Nr is the energy consumption rate for an IoT device (i.e., typically found on technical specification stickers on devices usually referred to as device watts) (i.e., whether the IoT device is turned on or off). The energy state of each IoT device is expressed numerically, where 0 indicates that the device is off and one suggests that it is on. Td represents the timestamps of the IoT devices on/off state.

4.1- Energy Consumption and Cost Aggregation for an IoT Device

Whenever a building manager m or a faculty member f requests the estimated energy consumption of an IoT device, the Energy Consumption and Cost Model aggregates the estimated energy consumption for a particular IoT device d, denoted N (d, t0, t), from the Remote Controller history records as in Eq.1

$$O\ (d,\ t_0,\ t) = N\ (d,\ t_0,\ t)\ {*}\text{€} \ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

Denotes the actual operating hours of the IoT device d in a period aggregated from the IoT device's energy status S d in the Remote Controller history records (Rh). N r(d) is the energy consumption rate for the IoT device d (i.e., also called Wattage of the IoT device). The result of this equation will be in kWh. Whenever a building manager m or a faculty member f requests the estimated energy cost of an IoT device, the Energy Consumption and Cost Model aggregates the estimated energy cost for a particular IoT device d, denoted O (d, t0, t), from the Remote Controller history records as in Eq. (2)

$$O\ (d,\ t_0,\ t) = N\ (d,\ t_0,\ t)\ {*}\text{€} \ldots\ldots\ldots\ldots\ldots\ldots\ (2)$$

N (d, t0, t) is the estimated energy consumption for a particular IoT device d in a period, and ε is the energy cost rate (i.e., according to SEC rates or Electricity tariffs). For example, suppose an IoT device's energy consumption rate (i.e., Wattage) is 1000 watts and the actual operating hours of the IoT device40 are 50 h. In that case, the estimated energy consumption for the IoT device is 50 kWh (i.e., 50,000 Watts Hours).

Based on the estimated energy consumption for the IoT device, we assume that the energy cost rate (i.e., according to SEC electricity tariff for governmental institutes) is 0.32 Saudi Riyals (SARs). The estimated energy cost for the IoT device is 16 SAR.

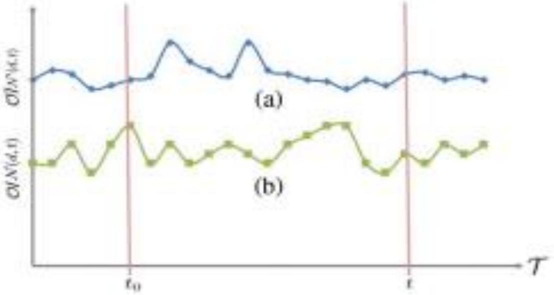


Figure 2: Energy conservation and money-saving percentages aggregation for an IoT device

4.2 Energy Consumption and Cost Aggregation for a Smart Classroom

Whenever a building manager m or a faculty member f requests the estimated energy consumption of a smart classroom, the Energy Consumption and Cost Model aggregates the estimated energy consumption for a particular intelligent classroom c, denoted N (c, d, t 0, t), from the Remote Controller history records as shown in Eq. 3)

$$N\ (c,\ d,\ t_0,\ t) = €_{d=1}^{C(d)}\ \nabla SD(c,\ d,\ t) * N_r(c,\ d) \text{.……………} (3)$$

where C (d) denotes the IoT devices in intelligent classroom c and |C (d)| represents the total number of IoT devices in brilliant classroom c. Δ S d (c, d, t) is the actual operating hours of the d th IoT device in the c th smart classroom in a period aggregated from the IoT device's energy status S_d in the Remote Controller history records (Rh). N r (c, d) is the energy consumption rate for the d th IoT device in the c th smart classroom (i.e., the result of this equation will also be in kWh). Whenever a building manager m or a faculty member f requests the estimated energy cost of a smart classroom, the Energy Consumption and Cost Model aggregates the estimated energy cost for a particular intelligent classroom c, denoted O (c, d, t 0, t), from the Remote Controller history records as shown in Eq.(4).

$$O\ (c,\ d,\ t_0,\ t) = €_{d=1}^{C(d)}\ N\ (c,\ d,\ t) * € \text{……….} (4)$$

where C(d) denotes the IoT devices in intelligent classroom c and |C(d)| represents the total number of IoT devices in brilliant classroom c. N (c, d, t0, t) is the estimated energy consumption for the dth IoT device in the c th smart classroom. ε is the energy cost rate (i.e., according to SEC rates or Electricity Tariff)

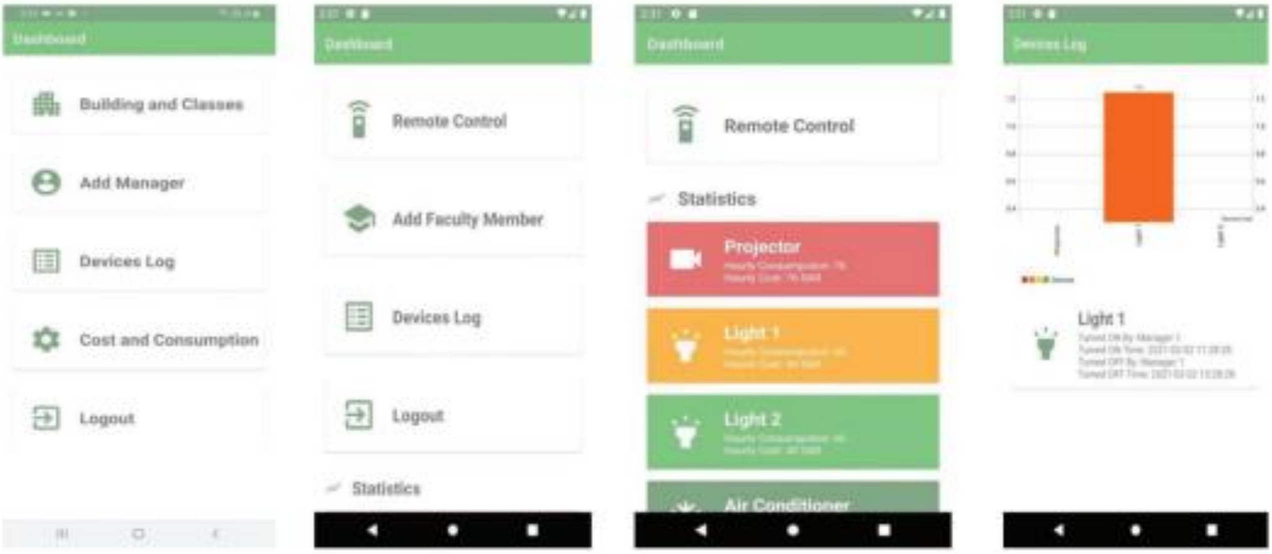
4- Implementation and Experimental Evaluation

The IoT-based energy conservation innovative classroom system is implemented using Arduino UNO Wi-Fi REV2 for monitoring and controlling IoT devices, Android Studio for developing the Graphical User Interface (GUI), MySQL 8.0.27 for database, and PHP for the mobile application backend. The proposed system is validated in a real-world scenario in a classroom at the college of computer science and engineering. The classroom consists of 4 units of 18,000 BTU air conditioners, 10 LED lights, and a wireless projector. The IoT devices' energy consumption rate is detailed in Tab. 1 (i.e., all of these energy consumption rates were entered by the Admin after the devices were installed).

Table 1: IoT devices' energy consumption rate

IoT device	N r(d)
18,000 BTU air conditioner	2.25 kWh
LED light	18 W
Wireless projector	200w

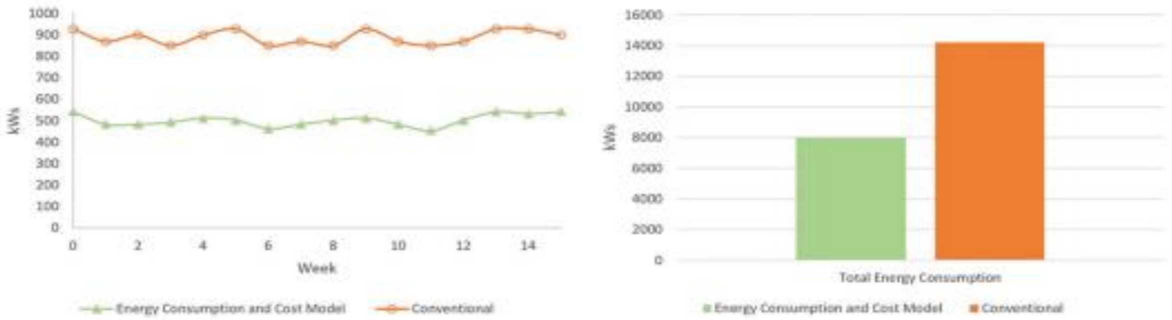
We have implemented several GUIs for the faculty members, building managers, and the Admin for implementing the IoT-based energy conservation innovative classroom system. Fig. 3 showcases some of the GUIs. For example, Fig. 3a illustrates the Admin's dashboard where she can add smart education buildings and bright classrooms, add building managers, add the energy consumption rate for the IoT device d and the energy cost rate (i.e., E, according to SEC rates and check the IoT devices logs. Fig. 3b illustrates the building manager's dashboard where she can remotely turn on or off IoT devices in the smart classroom using the remote control, add faculty members, check the IoT devices logs, and access statistics related to the estimated energy consumption and cost of the IoT Device, the smart classroom, or the intelligent education building. Fig. 3c illustrates the faculty member's dashboard where she can remotely turn on or off IoT devices in the smart classroom using the remote control and access statistics related to the estimated energy consumption and cost of the IoT Device or the smart classroom. Fig. 3d illustrates the IoT devices log where the energy consumption and cost of each IoT device can be monitored in real-time, the device's current status (e.g., turned on or off), the user who controlled the IoT device, and the time stamp.



(a) Admin Dashboard
(b) Building Manager Dashboard
(c) Faculty Member Dashboard
(d) Devices Log

Figure 3: IoT-based energy conservation smart classroom system GUIs

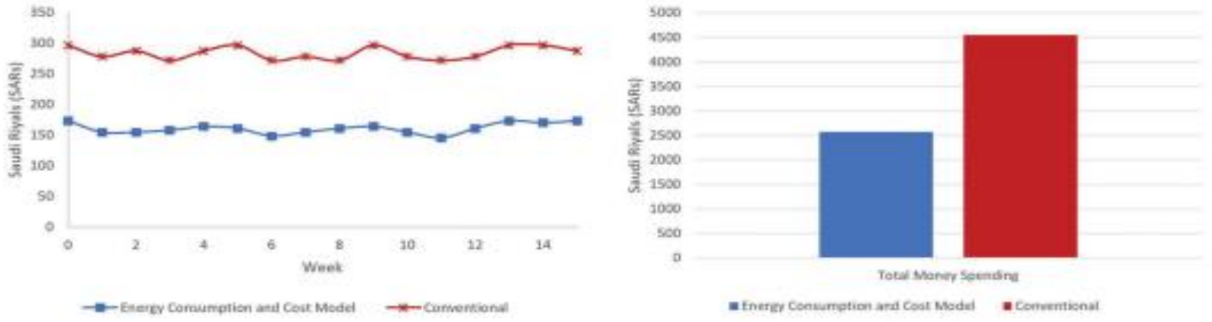
Figure 4: Remote control running and testing



(a) Energy Consumption Analysis (b) Energy Conservation Analysis

Figure 5: Energy consumption and conservation experimental evaluation

Fig. 6 illustrates the energy cost and saving experimental evaluation. Fig. 6a shows the energy cost for two experimental settings: (i) conventional model (i.e., without using our proposed approach features) and (ii) Energy consumption and cost model (i.e., while using our proposed approach features). From Fig. 6a, we note that energy cost results from the conventional model are significantly higher than energy cost results from the energy consumption and cost model through the 15 weeks. Fig. 6b shows the total spending for the energy consumption and cost model and the conventional model. From Fig. 6b, we can observe that the energy cost saving is approximately 1977 SAR (i.e., around 527$ USD) after using the energy consumption and cost model for 14 weeks. Specifically, the energy cost saving percentage for the intelligent classroom is 43.7%, based on



(a) Energy Cost Analysis (b) Energy Cost Saving Analysis

Figure 6: Energy cost and saving experimental evaluation

6 Conclusion

The Internet of Things is one of the vital energy-saving technologies contributing to the world's greener and more energy-efficient. This article describes the design and implementation of an IoT-based smart classroom energy-saving system that helps with energy conservation in the educational sector. We present a novel energy consumption and cost model for the recommended method. We especially developed an IoT-based intelligent classroom system for energy conservation that enables the user to access and manage IoT devices in real-time and analyses statistics about estimated energy usage and expected energy cost (e.g., IoT device, classroom, and education building). In this research, we present energy consumption and cost model that, for each IoT device, classroom, and educational facility, aggregates estimated energy consumption and estimated energy cost (i.e., following SEC rates) in real time. While compared to data gathered when the system wasn't in use, the model also aggregates the estimated energy conservation percentage and estimated financial savings % in real time. The testing outcomes show that in comparison to present energy sources, the suggested system may result in energy and financial savings of 43.7%. We hope to enhance our proposed approach in the future by integrating occupancy sensors to turn on and off IoT devices automatically. The system's expansion to incorporate the entire smart school building will be a crucial component of our future study.

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