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Trends and Challenges of Internet-of-Things in the Educational Domain

Ahmad Anwar Zainuddin*[1], Soumik Bhattacharjee[1], Shivank Kalliat[1], Sahara Shrestha[1], Sivaranjini Sivaraman[1], Muhammad Maaz Khalique[1], Denan Raj Naidu[1] and Puvanaah Manokaran[1]

[1]*Manipal International University, MIU Boulevard, Putra Nilai, 71800, Negeri Sembilan, Malaysia.*

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ABSTRACT

The advancements in the field of information technology in recent years have been very influential in affecting all domains that can utilize the power of data analysis for making decisions. Such domains that have been seeing new ideas implemented in their conventional methods are that of education and training. The advent of Internet of Things (IoT) has made monitoring and tracking of data very efficient. Data can come from a variety of sources, from wearables to smart class objects. To unlock the true potential from this technology, educators are urged to introduce IoT in their curriculum to help speed up the process. In this study, the various studies in the fields of wearables in education, vocational training, medicinal training, Green IoT and Smart City are reviewed. The implementations of Machine Learning (ML) in IoT are also explored, proving its viability in tasks such as bunching and classification. However, even with the abundant studies in the fields of IoT and education, its successful implementations are relatively scarce, thus bottlenecking current research.

1. INTRODUCTION

Internet of Things (IoT) enables physical objects to be arranged in a technical system to expand its usability in terms of ease and time consumption. It is to transform the idea of bridging the gap between the physical world and the machine world [1]. The number of connected devices is increasing enormously, and many predictions have been made in this regard. Based on Gartner's prediction, there were an estimated 20.8 billion new things that will be connected by 2020. The growth of IoT would consistently increase from 6 billion in 2015 to 27 billion by 2025 [2]. Despite the numerous reviews on various applications of IoT in different fields [1], [3]–[5], there is a need to address the progress of implementing IoT applications in education, which hints of the challenges and limitations yet to be faced by the aspect concerned. The paper aims to achieve this by gathering the diagnoses of IoT implementations in educational institutions, medical institution and training, technical education and training, Green IoT in education and wearable technology in education from recent literature. It has been projected that the fast growth of technologies such as cloud computing, and big data and analytics [1] shows how society has been eager to develop IoT society and encourage a new digital culture across the world. Succinctly, employment of IoT in education is still considered at its early stages but is highly encouraged.

2. MACHINE LEARNING ALGORITHMS INTO IOT/ SMART DATA

Machine Learning (ML) is a science that addresses the issue on how to create computer programs that enhance experience automatically [6]. There are algorithms that make predictions according to a given data set. It can be said to be a subset of artificial intelligence (AI). There are three types of ML; supervised, unsupervised and reinforcement. In supervised ML, the machine learning algorithm is trained on labelled data, whereas in unsupervised learning, on unlabelled data. The third type is reinforcement and can be described as the algorithm learns from situations using the trial-and-error process.

*Corresponding author:
E-mail address: Ahmad Anwar Zainuddin < ahmad.anwar@miu.edu.my >

2.1 Types of ML

Machine Learning (ML) can be categorized into three types such as supervised, unsupervised and reinforcement as shown in Figure 1. Supervised ML can be defined such that the machine learning algorithm is trained on labelled data. The algorithm is given a small dataset which it works with. The dataset has a clearly defined output. The algorithm is fed with more data until it performs as expected. It is the simplest method to be implemented in machine learning. Some examples of applications where supervised machine learning is used: Advertisement Popularity, Spam Classification and Face Recognition. Unsupervised ML can be defined such that the machine learning uses unlabelled data, which is an exact opposite approach of supervised machine learning. The algorithm attempts to understand the properties of data that it is fed. This algorithm organizes the data into groups or clusters. These groups and clusters can be comprehended by humans as well as other intelligent algorithms. Some of the areas where unsupervised learning is used are such as Recommender Systems, Buying Habits and Grouping User Logs. Finally, the reinforcement ML can be defined such that the algorithm learns from situations using the trial-and-error method. After every execution of the algorithm, the interpreter obtains an output and decides if the output is desired. If the result is favoured, then the outputs are reinforced whereas if unfavourable, then the outputs are discouraged. This way, in due time, with the help of the responses from the interpreter, the algorithm starts making less and less mistakes and starts giving desired outputs.

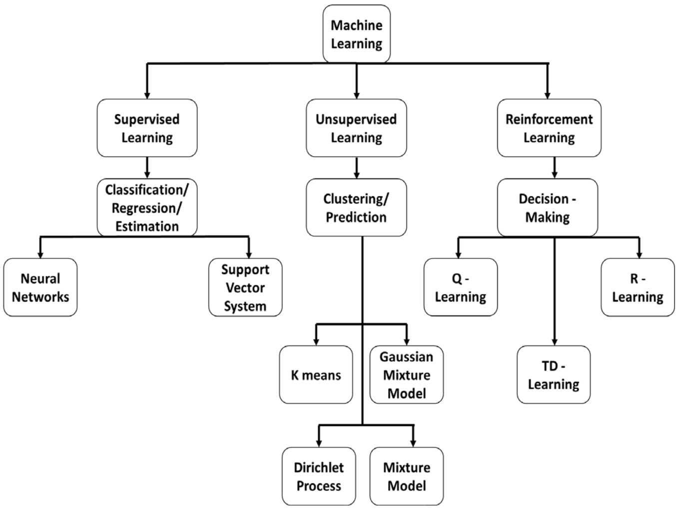

Fig. 1. Machine Learning can be categorized into three types: supervised, unsupervised and reinforcement learning.

2.2 ML-Based IoT Authentication

Internet of Things (IoT) is a system of electronic devices that are connected through a network, which can be used to collect and transfer data. IoT is a robust and open network of smart objects that can self-organize; exchange information, data and resources; and react and respond according to situations and environmental changes [7]. There are a wide range of applications of ML in the IoT field. These applications involve establishing techniques to secure IoT devices and connections, predict visitor behaviours in museums via IoT sensors and identify and classify devices connected in an IoT network.

In a paper by [8], ML-based IoT authentication, malware detection, access control and secure offloading schemes have been addressed, which helps in protecting data. ML techniques including supervised, unsupervised and reinforcement techniques were used for the attack models and for IoT devices and related security services. There are two machine learning techniques that can be used in securing IoT devices and the data it generates and streams. It is essential to protect devices from direct attacks through malware, or indirectly via jamming or interception. Multiple techniques have their own use case scenario and are undoubtedly required to make using these devices a safe and secure experience for its users. Due to the close integration facilitated by IoT between the physical and virtual environments, these networks are prone to security problems such as spoofing attacks, Denial of Service (DoS) attacks, jamming, distributed DoS (DDoS) attacks, eavesdropping, and malware. It is essential to secure personal data from attackers whereby the utilization of ML techniques have been shown to be effective for this endeavour. Four types of threat detection and prevention systems studied in this paper are: Learning-Based Access Control, Learning-Based Authentication, Secure IoT offloading with Learning, and Learning-Based Malware Detection.

A study [9] elaborated the usage of unsupervised learning to discern the hidden patterns and classes from data coming from IoT devices. To allow for decision making inside intelligent environments, these learning techniques are applied to IoT data. In this paper, two Cultural Heritage (CH) domains, museums namely, have been studied and the behaviour of its visitors have been evaluated using IoT sensors and ML techniques to utilize advanced technology in providing more widespread and interactive access to content. ML and IoT techniques are used in the CH domain to analyse visitors' movements and to figure out different types of visitors. This can offer personalized content and new experiences for any museum attraction. Two case studies have been provided in the paper of which museums have been fitted with IoT sensors. From the two case studies, a detailed analysis of the dataset has been done thus showing hidden behaviours and context-aware situations. Categorizing visitors from unstructured data coming from the IoT framework requires ML techniques to support decision making in real time and for context-aware situations that are useful for managing the intelligent environments. Thus, it can be seen that Machine Learning can be used in analysing and predicting data from IoT sensors in order to elevate the experience of the users (museum visitors). This data works in conjunction with the mobile information guides and other informative IoT devices in a Cultural Heritage domain to tailor personalized and interactive content for its users.

There is a study [10] on the use of machine learning with respect to traffic data of an IoT network to accurately identify connected IoT devices. A two-stage meta classifier was trained with the help of supervised learning. In its first stage, it helps in distinguishing between traffic created by IoT and non-IoT devices. In the next stage, each IoT device is categorized into a certain device class. The overall IoT classification accuracy of this model amounts to 99.281%. The types of devices used included smartphones, printers, laptops, baby monitors, etc. Not all these devices have IoT capabilities, and it is up to the trained classifier to identify and classify each device. This is done by analysing the traffic data generated by each device and after running the two algorithms, they have derived a session data to differentiate between an IoT device and a non-IoT device. This technique can be used to identify a device down to its make and model and is highly feasible to be used in real situations. Therefore, these techniques and algorithms allow for a better way to manage IoT networks by allowing for highly accurate classification of connected devices in the network. This was done by training classifiers that can read traffic data and evaluate it using the given algorithms. This can have a lot of real-world use in organizations with a lot of devices connected to a network in order to identify which device is an IoT device and what each device is.

2.3 Machine Learning Algorithms Taxonomy That Can Be Adopted in IoT

The reason for AI is to instruct personal computers (PCs) to execute assignments without human intercession. Extensive uses such as genomics, long-range informal contact, risk investigation generate an extraordinarily large measure of information, which can be extracted to obtain information from a cycle, client, or association. Eventually, AI calculations comprise distinguishing and approving models to improve an exhibition rule utilizing verifiable, present, and future information. Information mining is the way toward separating or recognizing designs in a dataset.

The IoT is a game plan connection of interlinked figurines, mechanical and advanced devices, papers, animals, or humans. This connection which has specific unique identifiers (UIDs) and the ability to pass data over an interaction without anticipating the human or human-to-PC association [11]. A sequence of sample data is used as an input called a training set to allow an algorithm to learn. In general, the three key classes of learning are supervised, unsupervised and reinforced in the taxonomy of ML algorithms [12]–[14]. From a casual point of view, the planning collection involves the testing of info vectors and their comparison, otherwise known as names, of suitable objective vectors. No names are required for the training in solo learning. Supporting learning handles the question of learning the correct activity or arrangement of moves to amplify the findings. Supervised and solo learning are still commonly implemented in the IoT intelligent knowledge test. The purpose of supervised learning is to learn how to foresee the appropriate yield vector for a certain knowledge vector [15]. Applications known as arrangement orders in which objective marks contain a small number of distinct groups. Situations where objective marks are made from at least one consistent factor are referred to as relapse undertakings [16]. Characterizing the objective of unsupervised learning is problematic. One of the important objectives is to differentiate between fair groups of comparable examples within knowledge, known as bunching [17]. In addition, the goal may be to expose a valuable inner image of the information by pre-processing the first information variable to transfer it to another variable space [18]. This pre-processing stage will radically boost the outcome of the subsequent measurement of the AI and is called the highlight extraction.

3. Review Studies in IoT

There was detailed research on the analysis and implementation of IoT in various fields and an unclear relationship was found between education and IoT applications. [19]. A study by [20] reviewed IoT framework security and a thorough review of the hardware, architecture, smart applications, and security features found have been carried out. In a review study by [21] an intricate review was carried out to list the open issues and obstacles for consideration in IoT research. Multiple IoT access control models, architectures, and protocols have been reviewed in a report [22]. In another review study, the usage of machine learning, as well as the advances in machine learning methods were considered [23]. In a systematic review study by [24], they examined the Unified Acceptance and Use of Technology Theories (UTAUT) considerations for understanding IoT adoption at the organizational level. Additionally, [25] based on IoT applications, conducted a review study on blockchain technologies.

Review studies based on IoT and education have also been conducted. [26] investigated IoT Smart Campus models and their applications. Implementations of IoT in classrooms, entrances and other services were researched. Similarly, [27] studied the use of IoT in smart classrooms and smart objects. This study addresses the adoption of IoT in education and the challenges that can be faced in this endeavour. However, this study as well as the one mentioned before on the application of IoT and education were limited in terms of focus, scope and breadth. This study was hence an attempt to review applications of IoT in the field of education, as well as to provide important hurdles that can be faced during the adoption of IoT in the educational domain.

3.1 IoT and Education Wearable Technology

Wearable devices are as much of a trendsetter as it is to become a necessary possession in our daily lives. These devices, which are technological devices worn on a user's body can be worn as any kind of merchandise, such as eyewear, wristwatches, clothing or even footwear [28]. Wearables can be categorized into wearable health technologies with main purposes of medical attention as shown in Figure 2. Textile technologies can be worn as a piece of clothing or fashion while consumer electronics are made into portable devices yet somewhat wearable. In recent years, smart glasses are quite popular as a day-to-day device. Such a device is the Google Glass. These are used by teachers and students to interact in flipped classrooms. Here, natural language, voice commands and a touch panel are used to share information. Hands-free recording and transmission of what is seen by the user can be easily presented independent of the visual presentation [29].

Figure 3 shows a workflow of the Google Lens and how it delivers the results. It is undeniable that this device serves the best to educators who fetch for quick information, flexible in sharing and opportunities for seamless collaboration. Not only in institutions, [30] prepared a log of training on paediatric surgery by wearing it on a stretch for four consecutive days, while also finding possible applicability. Through this exploratory study, it was found that despite taking time to get used to wearing the device while on operation, it exhibits useful applications during service, such as photo and video recording, hands-free telephone calls, billing codes and internet surveys that were of immense convenience and well noted. Another use case was seen by [31] who transmitted operations to a cell phone.

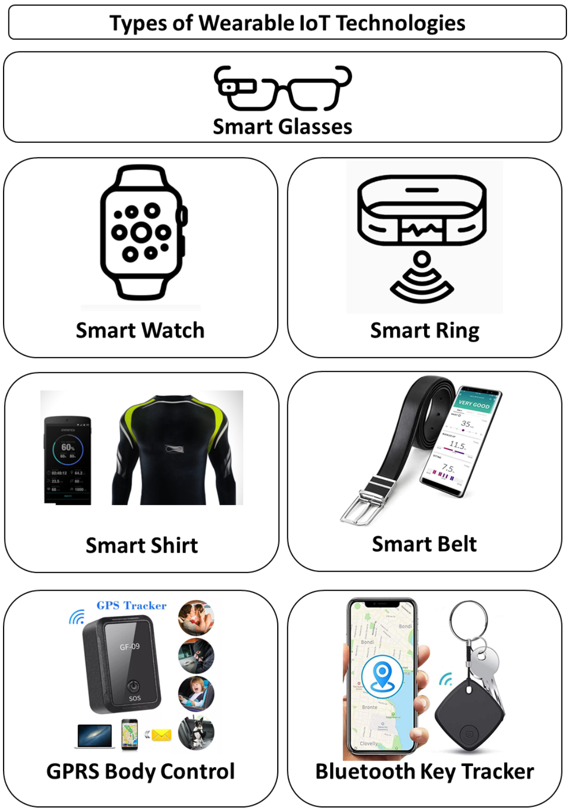

Fig. 2. Wearables can be categorized into wearable health technologies with main purposes of medical attention

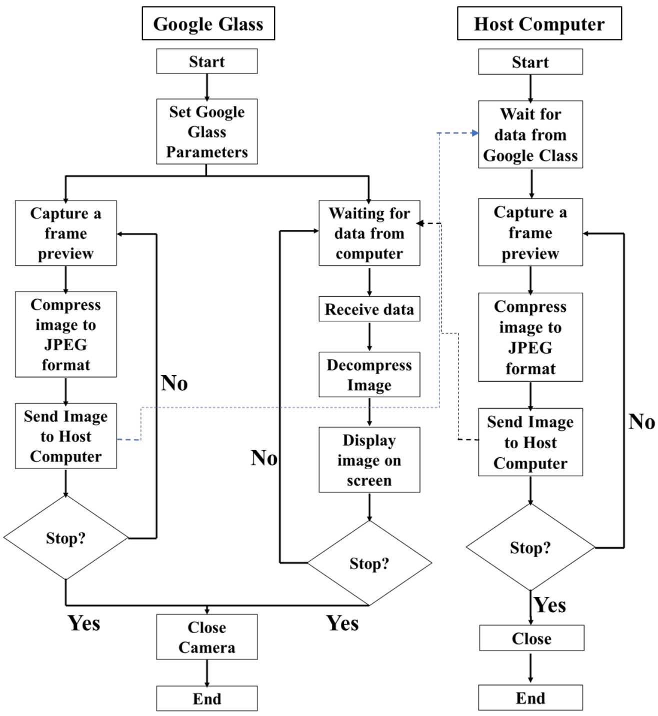

Fig. 3. A workflow of the Google Lens and how it delivers the results.

3.2 Vocational Education and Training IoT

IoT has been used in vocational education and training. It helps in enhancing the teaching-learning process between teachers and students. Many advantages can be seen in using IoT in vocational training. It creates a safer environment and helps in self-directed learning. It also helps in creating quality students [32]. ICT and IoT solutions also improve workplace safety. According to [33], linked to vocational education and training, the data obtained will be analysed in order to identify the incorrect ways in which the machine can be used to establish a dangerous situation. Following the results, the students can be guided on healthy job procedures. Data analytics can be used to identify data abnormalities in contrast to the usual machine data [34]. This enables the prediction of student-dangerous computer failures. The computer can be stopped in unsafe circumstances. Based on the appropriate ability level, the instructor may also identify the students who can use a particular system. For example, a student must log on to the computer with fingerprint authentication. Safety is also enhanced by the fact that machines equipped with the correct type of sensor can identify human limbs. Therefore, these machines help to restrict possible danger to humans. Moreover, smart machines can avoid risky situations created by reckless people. For example, if a dangerous situation occurs, the computer will automatically stop the actuator movement. When an accident happens for whatever cause, the data obtained will be used to evaluate the accident. For instance, the course of events can be analysed later using the stored footage. The stored data may suggest that the student, for example, had enough capacity to use the system independently.

3.3 Green IoT in Education

Green IoT has also been used in education. It refers to the study of designing, manufacturing, using and disposing of systems and its subsystems [35]. Figure 4 shows the advantages of Green IoT in terms of the environment in the industry. Green IT helps in reducing electrical power consumption, which helps to bring positive impacts to the environment and economics. The system includes servers and computers, and its subsystems are printers, monitors, and networking systems. Green IoT can be applied through energy conservation, switching off systems when not required, management of power and having eco-friendly designs. The advantages of using Green IoT are it helps in reducing costs, power consumption, saving space, and overall improving the performance of the system.

Green IT has also helped in creating a healthy climate. Optimal use of resources, energy efficiency, the participation of stakeholders, renewable energy, Green ICT committee operations, institutional policy and legislation have all led to the successful implementation of Green IT [36]. The use of Green IoT in smart classes comes with advantages as well as some challenges [37].

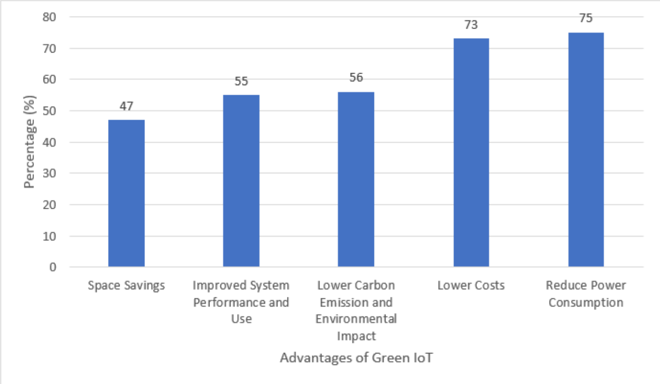

Fig. 4. Advantages of Green IoT [35]

3.4 IoT in Medical Education and Training IoT

With the advancement in information technology and manufacturing of more and more devices, the design and implementation of IoT applications are becoming popular. Its education however has not been that successful [26]. Even with the availability of jobs around IoT, students do not engage in them due to the lack of proper exposure and experience. Higher education systems have not incorporated IoT-related courses in their STEM curriculum. Being hopeful about the prediction that in the next 5 to 10 years, IoT technology could be the key technology [19], educators are keen to offer IoT courses in their curriculum. There are various kinds of digital learning that are introduced under the field of IoT technologies—these are Electronic Learning using computing devices such as desktops and networks to learn [38], Mobile Learning using any kind of hand-held or portable devices [39], [40] and Ubiquitous Learning using portable devices and additional cross platform environments for enriched learning experiences [41].

A study conducted by [26] reviewed the IoT smart campus models where several technologies are introduced. These applications are for example, IoT, flipped class IoT, IoT and student feedback systems. The IoT and IoT heating systems, are available for everyday use for pupils, teachers, employees, and other staff. A similar study was also done by [27] which highlighted the possibilities for IoT applications in education and the potential obstacles that limit education. However, these studies do not provide full scope of the concerned objective.

Recent studies around IoT technologies have been focused on key challenges of the employment of IoT in education. A study by [42] explains how mobile education using cloud technology can provide easy access to digital learning with more data storage. In northern Thailand, some primary schools have taken a leap with IoET (Internet of "Educational Things") in underprivileged areas [43]. They have incorporated mobile learning by providing one tablet device to each student thus coming up with an effective solution to the unused tablets. Moreover, [44] addresses the different avenues that needs to be looked upon to institutionalize IoT systems. It introduces the relationship between IoT, cloud computing and emerging learning theory as "connectivism." Accordingly, an all-inclusive educational institution strategy is to alter curriculum, teacher preparation, educational philosophy, data security, legal and political concerns, and develop capital and proper IoT infrastructure. Another proposal was made from a study by [45] of combining IoT-based learning with current laboratory ventures. A similar type of framework integrated into software engineering, with system analytics and design courses, was another idea that has had a positive feedback from students. Other studies such as [46] shows the importance of combining IoT practical modules with existing courses in higher education.

A study by [47], which was further verified by the findings of [46], ventured on the contents of a proposed course specially designed for aspirants in IoT specialization. This study was even stronger than others as it provided a framework for all students irrespective of their educational background. A transdisciplinary curriculum related to the ACM/IEEE 2013 Computing Curricula Knowledge Areas was suggested by integrating different disciplines. Teaching development strategies were also pointed out in this study from which a few IoT teaching methods were discussed. With respect to personalized learning, many studies have proposed IoT systems, one of which by [48] showed how students of liberal arts can create an IoT system in a procedural manner for their own needs in their field. Again, [49] in his study, designed an IoT learning kit used with blockchain technology and further elaborated on how the two technologies relate to each other. There is an IoT model [50] that can be used to build smart classrooms, smart car parks and provide university students with smart education. Similarly, [51] proposed a system for incorporating IoT in education. The system is rather a unique 3D scheme for IoT that explained in three tiers on how to adopt IoT in academic sectors. The education field might have seen a vast range of research on the implementation of IoT technologies, however, the Medical and Training industry has not had similar exposures to such extent. One of the studies done in this regard is by [41] which proposed a system that allows students to interact with objects of study in their respective fields. Results showed that this system aided the students learning experience as well as the teacher's teaching process. Recently, a major development in research based on use of IoT in medical and training field is the use of case-based learning (CBL) through flipped learning and IoT. These have shown significant change in learning experiences for medical students [52].

There have been numerous research studies on the applications of IoT for the purpose of learning and education. Nonetheless, it is inevitable to say that a horizon of possibilities is still yet to be explored when it comes to smart learning. We live in a century where Information and Communication Technology is integrated within almost every daily activity in almost all developing countries [26]. Now, all countries are implementing IoT in some field or the other to boost their economy and international appeal. More schools are adopting new methods to teach and make students like the process of learning through IoT devices.

3.5 IoT in Smart City Application

Smart City consists of ICTs to build, submit and advance sustainable advancements to resolve the challenges of urban growth. ICT is an intelligent network that supports objects to stay connected and transmits data to machines with wireless connections and cloud. Our lives have changed so much since the last decade because of smart cities. The idea of smart cities has played an invaluable role in the field of science and industry [53]. Due to the rise in populace and complexity of city infrastructure, cities looking for ways to manage the difficulties of big-scale urbanization. The basic components of a secure Smart City IoT Analysis consist of Black Networks, AKA TTP, Centralized Registry & Primary Administration Systems (as illustrated in Figure 5). This architecture is built for networks that use heterogenous technologies and works across numerous types of devices. The technologies are used to overcome the resource restrictions of IoT nodes. Black Networks are implemented to enable security features such as data privacy, confidentiality, integrity of data, and authentication of devices and users. TTPs are used to allow for efficient routing of encrypted data across nodes that are asleep for up to 90% of the time. Unified Registry are used to secure databases of IoT devices as well as their attributes. Key Management provides an external manager to handle authentication keys for IoT networks. IoT plays a pivotal role in the collection of city climate data. IoT can predict emergency conditions, such as earthquakes and volcanoes, and also enable cities to use live status updates. IoT helps each city relate to each other. The key objective of IoT is traffic control, water management and energy use. It enhances the lives of people. The aim of intelligent cities is to turn regional and urban regions into law-based places of growth. By adapting the smart city, government could lower public health, transport, and security expenditures to help the country stabilize its economy. Developers agree that intelligent city applications and structures need to be repaired, if possible, in the long term.

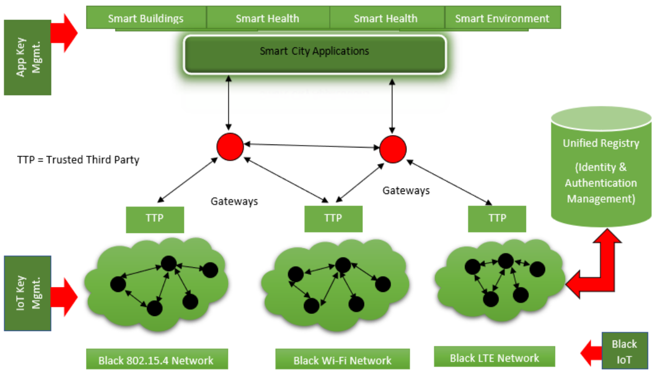

Fig. 5. The basic components of a secure Smart City IoT Analysis consisting of: Black Networks, trusted SDN IoT Analysis consist of: Black Networks, trusted SDN Controllers (AKA TTP), Unified Registry and Key Management Systems

3.6 Controller and Energy Management Systems

HOMER recommends two types of device and power leadership schemes, which are the load-following approach (LF) and cycle storage approach (CC). The load-following approach generates enough energy to satisfy the main load when a generator or grid is working. Renewable energy sources have lower priority targets such as charging storage banks or supplying the deferrable load. If economically beneficial, the generator can still boost and sell energy to the grid. On the other hand, in the cycle-charging strategy, the generator or grid works with complete energy to meet the main load demand. Surplus manufacturing of electricity comes to the fewer priority goals, such as supplying deferrable loads, loading the storage bank, and supplying the electrolyser; to decrease precedence, HOMER considers both load follow-up (LF) and fluid charging (CC) to ensure optimum power management of the microgrid. Based on the low price and elevated RE generations, HOMER will choose the greatest approach.

4. DISCUSSION AND IMPLICATIONS

This study was conducted to review the existing trends in employing IoT in the educational domain. IoT has been proven to provide opportunities for implementation in educational institutions for instructors and students. It can be used to provide access for students to connect to the institutes' learning tools from any device connected to the internet. It can also be used to track and analyse students' performance and achievements through sensors and wearable technologies [54]. It also allows integrating facial recognition or the use of RFID to automatically take the attendance of students and instructors. This also enables students to find quiet areas around the campus to study and provide additional lessons based on occupancy detection and tracking features [3]. IoT and flipped learning can be used in medical education to enable students pursuing medicine to take effective decisions and complement collaborative learning practices [52]. For vocational training, didactic tools to build effective training skills amongst students who are attempting to solve uncharted issues are using IoT devices [32]. Wearable technology can also be used to allow students to track their own learning behaviour and to better their interactive experience [55]. There are however a few challenges related to the application of IoT in education. The first of which would be to introduce IoT courses in the syllabus of Computer Science and Engineering students. This allows fresh graduates to have enough knowhow to work on IoT-related projects. Secondly, the same must be done with the university instructors, as they must be introduced to IoT to instructors and staff to acclimate them to its usage. As IoT is still in its embryonic stages, issues such as cost, range and battery life of IoT devices are still an issue. A fourth issue will be the adoption of machine learning applications in IoT based studies as their presence is both scarce and inadequate [56]. According to scholars, the fifth challenge would be to address security and privacy issues that might be the main hindrance to the adoption of IoT in education [57]. Sixth, the lack of use by developing countries of Green ICT in education is also a challenge [36]. The use and adoption of wearable technologies such as Google Glass in the medical education field is also a final challenge scholars must aim to conquer [58].

5. CONCLUSIONS

Much research has indicated the reliability of IoT facilities and educational applications. These research shows that IoT integration in education is currently in its early stages but has indeed evolved rapidly. It is regarded as an important method for successful learning and education. IoT systems have immense potential to provide higher education with significant values by addressing significant issues such as monitoring key resources, improving access to knowledge, creating smarter strategies and developing safer campuses and thereby increasing learning speed. With more in-depth research, the challenges for growth of IoT deployment in developing countries have been noticed. Next, limited labour force skill is one of the reasons for structural challenges in developing countries. It is also mentioned that while the rest of the world demands for more value-added products, these countries have a considerable share of value-added products. Moreover, weak security measures make the employment of IoT devices vulnerable in developing countries. There is an abundance of opportunities to work with especially on the students' learning experience with the implementation of IoT applications and the factors affecting it.

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