

The future of the Internet of things - the impact on education sector in developing countries

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Abstract

With the enormous developments and the increasing role of technology in nearly every aspect of life, conventional methods of education in a classroom appears to no longer be appealing and effective or learners of the 21st century. The increasing popularity of Internet of Things (IoT), where students can make use of wearable devices embedded with sensors that connects them with learning systems is the need of the time. The Internet of Things (IoT) allows individuals and objects to remain connected anywhere and at any time, preferably by means of a service and a network or path.

Students particularly in colleges and universities have progressively made a transition from paper-based books to that of Tablets and iPads which are equipped with various interactive apps and built-in graphics and simulations along with having the liberty of both space and time. The paper aims in discussing the different aspects of IoT within its productivity level which is equally useful for both learners and educators of the current time. The article will present an overview of IoT aspects and possible solutions that can be implemented within the education sector along with value added aspects within the education sector through IoT.

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1 Introduction

The Internet of Things (IoT) carry the power to change our world and if we are beginning to see the incredible impact, we are nevertheless only at the beginning of a radical evolution [1]. Soon every device you own – and virtually every object in existence – will be connected to the Internet. Whether it is through your cell phone, “wearable” devices, or everyday household appliances, we will be connected to the Internet of Things (IoT) in ways that cannot be even imagined [2].

The thermostat, alarm system, smoke detector, doorbell and refrigerator in households may already be “connected”, but the evolution is also beginning to be seen at the scale of cities. Thanks to better management of energy, water, transport and security, inhabitants are closer to their environment, which leads to the dream of a fully integrated, smart and sustainable city. Additionally, we are also witnessing an incredible buzz of activity and innovation at the factory level, where the potential of cyber-physical systems to improve productivity and efficiency in the production process is immense [3].

The Internet of Things (IoT) is the next big thing; markets are constantly on growth with the emergence of the latest technologies and improved connectivity according to the Gartner. A research company estimates that the locomotive and enterprise IoT market has grown by \$5.8 billion

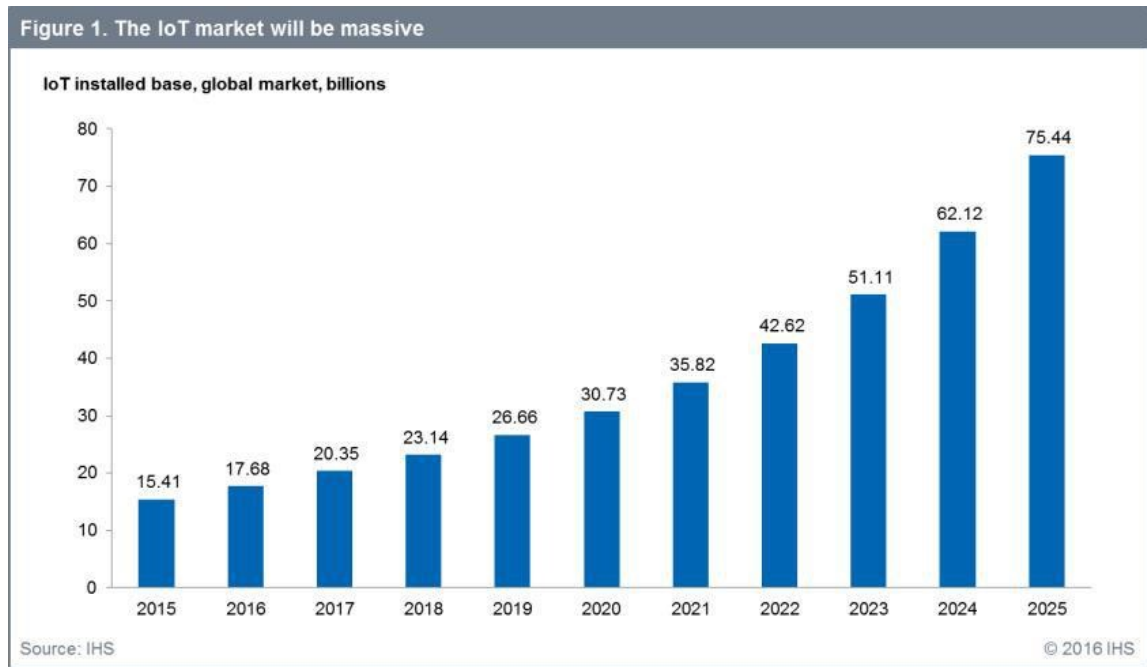


FIGURE 1. The IoT market.

in 2022, a 28% rise from 2019. Figures tend to vary when the question is to predict the quantity of internet-connected devices or IoT devices. Thus, we cannot neglect the IoT adoption and role that is incredibly high [4], as in Figure 1.

Even as companies look for means to use the IoT, they need to make sure that the issues are being understood. Data is crucial for business growth – it helps in making premeditated decisions. Companies that look to develop IoT could look for expert professionals of the field. Certainly, they will help to build the platforms for enterprises. These are powered by the Internet of Things.

The IoT and its growing acceptance ratio continue to progress and alter the method in which we work presently as well as in the near future [5]. With the discovery and launching of the internet, connectivity existed, which means IoT is nothing new. But since IoT is not only about connectivity, rather it also involves some other things such as data collected through connected devices which eventually means that with respect to data levels it is only recently, we have such enormous data.

Business owners need not look far to see the rapid adoption of the Internet of Things and the advantages that are available to the enterprise world. Now, anyone could access to the crucial data and information. Now, businesses companies can receive remote data from their actual location in real time. Due to the system developed through the connected devices, any person can access any type of information from any part of the world. In this way, individuals can conduct their business activities whether or not they are physically present [1].

IoT augments communication by formulating a network system of linked devices. This assures that communication is highly crystal clear and the aspect of inadequacy is also reduced. The



FIGURE 2. Edge Computing Market Report.

procedure through machines tend to communicate with each other are also made efficient [6]. The IoT also promotes automation as these devices are used in the management of daily tasks, thus improving the service quality as well as reduce the percentage of human involvement. To begin to earn the bounties of the Internet of Things, enterprises are in an urge to seek the development team that has the ability to understand the Internet of Things ecosystem along with how it drives the businesses to grow. So as to assure the success of the IoT, companies must prudently consider factors such as connectivity like that of edge computing and now 5G.

2 Edge computing and IoT

Edge computing basically refers to those devices that collect data from the huge data center. Previously, these devices were not equipped with the type of computing power that is seen presently. Most of the devices did not have such types of data storage capabilities that are being witnessed today. Conventionally, devices were not formulated to store massive amount of data and evaluate it. Therefore, they could be sent over the cloud for review. Today, these advanced devices are designed with built-in functionality that allows them to integrate technologies such as machine learning (ML) as well as analytics for extracting valuable insights from collected data [7].

Since information can be attained by means of business intelligence, it helped businesses to work with better informed resources that are primarily based upon advanced data. The latest features such as machine learning empower entrepreneurs or business people to process data speedily. This aspect serves to be cost effective and it is well streamlined as well. Additionally, storing data in a local device also helps in reducing bandwidth requirements and low latency, thereby reducing workload over the network. The emergence of speedy networks like that of 5G makes it easier for IoT development departments to work. More and more organizations are in a position to comprehend the value of harnessing the IoT and addressing the challenges associated with this ecosystem [8], as shown in Figure 2.

3 Global standardization

In various industries, problems arise due to fragmented IoT supply chains. Within these supply chains, there exist sensors that have been devised to communicate with each other. Additionally, an allied chain provides an all-inclusive operation as these sensors have the capabilities of understanding

each other so they work in an organized way. This means that all the suppliers are able to contribute towards the process. In case an aligned supply chain is created, that means vendor lock-in will be eradicated. In order to attain this, global standardization is rendered to be very important—whereby the organizations launch the interoperability of products and services so as to make the flow of information free between sensors [9].

One of the challenges of new technologies is the absence of interoperability and the same is true with IoT supply chains. Forming a standardized and interoperable platform will be important if companies in the optimization of their Internet of Things network.

4 IoT security issues

Although the Internet of Things has many advantages; however, for few certain limitations that businesses should be aware of. The first challenge faced by the IoT is a security issue. As more and more devices connect to the Internet, they have a wider surface for a potential cyberattack. The growing number of connected devices eventually means that the points of access for malevolent actors are also expanding. Such attacks can easily penetrate within a company's network from different access points [10]. For example, the development of a connected automobile today involves varying manufacturers, suppliers, along with systems sensors.

Hence, when the question is to determine the responsibility of security upon product completion, it becomes a challenge. However, endpoint safety is addressed through the usages of several other advanced technologies such as machine learning, artificial intelligence, and blockchain [11]. IT managers are making use of such innovative technologies for addressing their security vulnerabilities present in the network of Internet of Things.

5 IoT and 5G – the future

5G network was presented during 2019 for smartphones and tablets. This network launch greatly helped in transforming different aspects that are beyond mobile devices. It has speedy network connections, sprawling locations, and condensed latency features that go with connectivity—enable new use cases for the Internet of Things. The 5G network enables the business to collect data efficiently and very quick. This, in turn, enables more applications of the IoT while ensuring innovation [12]. Though 5G network is still operating in its infancy stage and it may lack the capability of completely change the industry of Internet of Things?

The entire world is gripping towards a fully connected future. Moreover, market drivers deliver added value through the connectivity of everything from road lights to home appliances to that of industrial robotics. Connecting things with each other has become a lot easier today with improvements in end devices and increased investments within IoT systems using the global standards. Edge cloud, cloud computing, improved safety, and the artificial intelligence are few aspects that have augmented the progression of the IoT ecosystem.

Essentially, IoT has changed businesses procedure and it has transformed the living standard of people. The latest innovation will expand in the coming years and new devices will continue to connect with the Internet. In the coming decade, unaccounted devices are expected to be connected globally, creating millions of dollars in economic value across many markets [13]. Most businesses use the Internet of Things to grow on a faster speed. Using the services of an enterprise helps in exploring the different ways it can leverage data collected from connected devices.

6 Predictions for the future of IoT

6.1 It is estimated that by 2025 there will be over 21 billion IoT devices

A quick assessment of the rapid growth of IoT in the past will give a clearer view of its future. Based on the analysis of IOT analytics more than 4.7 billion devices were connected to the internet in 2016 alone.

With the daily increase in technological advancements, IoT devices keep growing daily. By 2025, analytical estimates predict that more than 21 billion IoT devices will be connected to the Internet, sharing data and communicating with each other [14].

6.2 More cities and businesses will become smarter and more strategic

IoT technology will not only be used by consumers. By 2025, many cities and businesses will use the system and use it for optimal results and performance [15]. IoT technology saves time and energy. For this reason, cities and businesses will use IoT to save time and energy.

In other words, many cities around the world will be able to function thanks to automation. They will be able to manage things remotely, as well as having a systemic and intricately organized data collection system by means such as a video camera surveillance system, visitor kiosks and many more.

6.3 Artificial intelligence will continue to evolve bigger

Currently, the technology of artificial intelligence has made huge waves in the tech world. This widespread fame is not for nothing. Its application in businesses, multi-million-dollar companies and businesses has generated billions of dollars.

Also, the AI has improved and added values to many lives. In education, it has been used and is still being used to empower millions of users around the world. People with disabilities are not left out. Through a virtual assistant, AI technology has helped people with disabilities in several ways.

AI technology studies people's behavior patterns, attitudes and choices. It then uses the derived information to make specific recommendations to them whenever they search for something on the Internet. By 2025, artificial intelligence will be in high demand and will continue to be a big technology concept [16].

6.4 Routers will continue to get safer and smarter

Most IoT devices are at home. Most of them do not come with a security system installed. For this reason, they are very vulnerable to cyber intrusions. This means that your IoT devices can be hijacked and controlled by a third party, or better, a hacker, if they are not secure. This is where home routers come in handy.

Basically, the home router is the internet entry point into your home. It is like the entrance that must first be crossed before accessing the Internet at home. With Routers connected to your IoT devices, your home internet connection is walled off and hardened. It is no longer an unfenced space vulnerable to attack.

While not all of your devices are protected, routers provide strong security at the point of entry. Apart from you, nothing can pass through a firewall protected by a router. Typical routers offer some security like passwords, firewalls, as well as the ability to configure them (routers) with certain devices on your network.

So, with the improvement in IoT technology, router manufacturers will step up their game and provide stronger security measures in the future.

6.5 The auto industry will step up its games

It may not have crossed your mind, but in reality, cars correspond to IoT devices. With the arrival of the 5G network, the automobile industry will experience a great breakthrough and bring out incredible automobiles that will delight the eyes.

The development of driverless cars and all other connected vehicles on the road will have a huge advantage because of the rapid data that will be generated.

With the boom in IoT technology and artificial intelligence, the automotive industry is expected to manufacture internet-controlled cars that are connected not only to smartphones but to other cars on the road [17]. Such a connection has many advantages. One of them is the prevention of road accidents.

7 Smart devices and cities: how is the IoT changing our daily lives?

The big revolution in daily life through the IoT is yet to come. It is hard to guess how much the IoT will change our lives. As a matter of fact, not everyone today has started living in a smart home or use wearable devices. Inventions like that of automated cash register systems, smart surveillance cameras from distance and self-monitoring workshops. They operate largely invisibly in daily life or remain in the background. IoT environment confirms that we are surrounded by computer systems that gather data and transmit it over the Internet [18]. If such devices are used within its own four walls, then they completely penetrate into the private room.

But a smart home also has many advantages for populations in a particular area: based upon personal as well as activity-related data, it acts with foresight and simplifies numerous daily practices. Household appliances are self-regulating and do not require to be monitored. A self-switching wood-burning stove or a self-closing apartment door offer more security.

Several networked devices also tend to react to different behavioral patterns: a fitness bracelet, for example, promotes a healthy lifestyle and alerts the user when it senses a lack of exercise. However, human needs are only partially predictable. Moreover, this technology raises the question: what if things increasingly dictate our way of life? For example, how are health insurance companies going to structure their rates in the future if they are given a vision within a fitness program that does not meet their health policy standards? It's not just ethics experts who deal with these issues. IT experts have also discussed the potential shortcomings of IoT. They are considering a sort of Hippocratic Oath for software developers. Here, one thing is definite for the Smart-Home devices. They are effectively in use practically. As an example: the adaptive radiator thermostat from Nest company taken over by Google can be used. It monitors and memorizes the heating habits of residents' and adjusts the temperature automatically. Similarly, an integrated motion detector identifies the residents presence at home and close the heating system when absent. Certainly, this activity saves energy, heating costs, and increases living comfort. If residents come home earlier, they can preheat the apartment remotely [19].

IoT innovations already being tested in some cities show what can be made probable in the public sector in the near future. In case these are used on a global basis. The IoT has the potential to make transport, road traffic and waste collection more efficient. It would create an entire infrastructure of networked streetlights, traffic lights, garbage containers, and building facades that would collect data through sensors.

In Santander, a Spanish city, Smart City will be a reality. Within the narrow streets of the city center, thousands of sensors measure the volume of traffic. An app provides information on busy traffic lanes and guides drivers to a free parking space. In Amsterdam, smart streetlights provide appropriate light power. When there is no one nearby, they automatically turn off. It not only reduces light pollution but also saves energy costs.

8 The foundations of a fourth industrial revolution

What is the Internet of Things? What does Industry 4.0 mean? After steam engines, assembly lines and digitalization, the Internet of Things is certainly the engine of a fourth industrial revolution. Smart factories manage overall production process by themselves. It is a signal to the dawn of a novel era. These factories accelerate their production with increased proficiency and reduced expenditure. For example, in a networked factory, materials are equipped with small RFID chips indicating which machine will be next in the processing step. Machines use sensors to indicate critical conditions. In order to assure that every process flows on smoothly, they flag all material and repair needs [20].

9 Opportunities and risks of Industry 4.0 and digital marketing

The Internet of Things makes it possible to optimize production phases of a product. In addition, it could seamlessly in all the departments involved. It might help in product development, production, marketing to delivery and recycling. In addition, networked and self-learning machines make it possible to better respond to individual customer needs. To manufacture customized products, it is not necessary to carry out human control or plant transformation every time [21]. Adidas already produces personalized sports shoes in this way.

There is huge potential of the Internet of Things in the field of marketing. For instance, retail industry is reaping benefits from geo-targeting. The iBeacons are used for sending signals to smart handheld devices that provide information related to special offers or guide buyers of organic products directly to the corresponding offers. Drink vending machines on the Internet are able to report vacancies or damage. If the sensors measure hot temperatures, prices of drink can be automatically adjusted based on the expected increase in demand.

Another example is whiskey maker Johnnie Walker's smart bottles. The latter has developed bottles that communicate with the customer's mobile phone via NFC (Near Field Communication). The sensors connected with the neck of the bottle label gathers info. In this way, the organization can manage tracking of the supply chain and the entire customer journey. Installed sensors will register whether the whiskey bottle is open or closed. Based upon this information, the buyer will receive information or tips for the product so as to gain a pleasant consumption via his smartphone. It also creates an added incentive to purchase and enhances the product experience. Networked elements are therefore able to collect data and link it to each other throughout the product life cycle. Taking into account the consumer data obtained, company can communicate appropriate messages through advertising.

The potential of the Internet of Things in terms of economic is enormous. According to a study by McKinsey, the IoT in 2025 is expected to bring around US\$11.1 trillion to the economy [22].

However, Industry 4.0 is also linked with various risks: A comprehensive networking offers hackers several points of attack and the risk of data protection breaches and industrial intelligence increases. If the production as well as maintenance procedures are deputized to machines, it will



FIGURE 3. Source: Verified Market Research (2021)

replace human labor. And this does not only apply to repetitive and hazardous jobs but also to the jobs that are currently used by many people to earn a living [23].

However, experts still disagree on where and by how much the IoT will change the human life and world of work. On one side, digitalization creates fresh jobs and smart devices are practically to be used in many fields only as a human assistant. On the other side, some economists expect Industry 4.0 to go hand in hand with a global rationalization of employment. Andrew (MIT) assumes, for example, that by the middle of the century about half the jobs will have been lost. A study from the University of Oxford comes to a similar conclusion.

10 The IoT market in education

IoT Education Market was \$6.05 Billion by 2020 and is anticipated to reach \$26.8 Billion by the year 2028 with a CAGR of 20.06% from 2021 to 2028 [24]. There is a growing trend towards improving operational efficiency as well as management of connected devices, which infers a rise within IoT education market. Major players in the IoT industry are coming up with various options such as forming the Open Mobile Alliance (OMA) to that of standardized protocols, as shown in Figure 3

The Internet of Things (IoT) has a huge potential to transform education by radically changing the way including primary, secondary and higher educational institutions collect data, interface with users and automate processes. IoT consists of the networking of physical objects by using embedded sensors, actuators and others intelligent devices that can gather and convey information about activities throughout the campus in real time. When IoT is combined with the newest technologies such as the mobility of users and data analysis, it brings a new paradigm in education

[25], as shown in Figure 4. The IoT enables institutions of:

- Providing students with ways to learn more innovatively, with more dynamic custom methods, like digital textbooks or learning based on the game.
- Change the course system and conducting teacher tests with smart audio-visual equipment, like recorders digital video for playback and online testing.
- Streamline procedures to school superintendents through the proactive surveillance of serious infrastructure and create effective processes that are more profitable for heating, ventilation, air conditioning, management of lighting and equipment.
- Arrange secure surroundings for every student and teacher with smart door locks, digital surveillance cameras and movement of school buses.

11 Scenarios for IoT in education

Solution of IoT promises to not only make educational institutions smarter but a lot more efficient in their actions as well. IoT technology holds immense potential in redefining how teachers, students, and other administrative staff tend to work together and connect with the technology and equipment within the classroom environment. Certainly, it will help participants in improving the learning process and education outcomes with reduced costs. Examples of IoT solutions for Education in developing countries include:

- Smart whiteboards and several other digital media interactive tools to collect and analyze data that students and teachers can use in the classroom anytime or anywhere to optimize their educational process and the results.
- Intelligent solutions such as sensors of temperature and equipment for ventilation, heating and air conditioning for reducing energy consumption along with automating operational management.
- Student tracking devices, smart student cards, attendance, and school transport tracking systems as well as parking sensors that control incoming and outgoing students.
- Facial recognition systems, surveillance cameras, and wireless door locks that offer security to students, teachers and supporting staff members.
- Improved research programs through automated and advanced systems in key areas of study, like agriculture, engineering and medicine [26].

12 The challenges of IoT deployment

IoT enables flow of data, indicating a real-time test for performance, operations and management of network structure with increased security risks of any origin. To resolve these difficulties, network administrators in schools should use their customary network designs so as to equip the network with a higher degree of intellect, automation and the security. Schools and universities need economical network infrastructure and the ability to handle large data streams safely and efficiently. The infrastructure must:

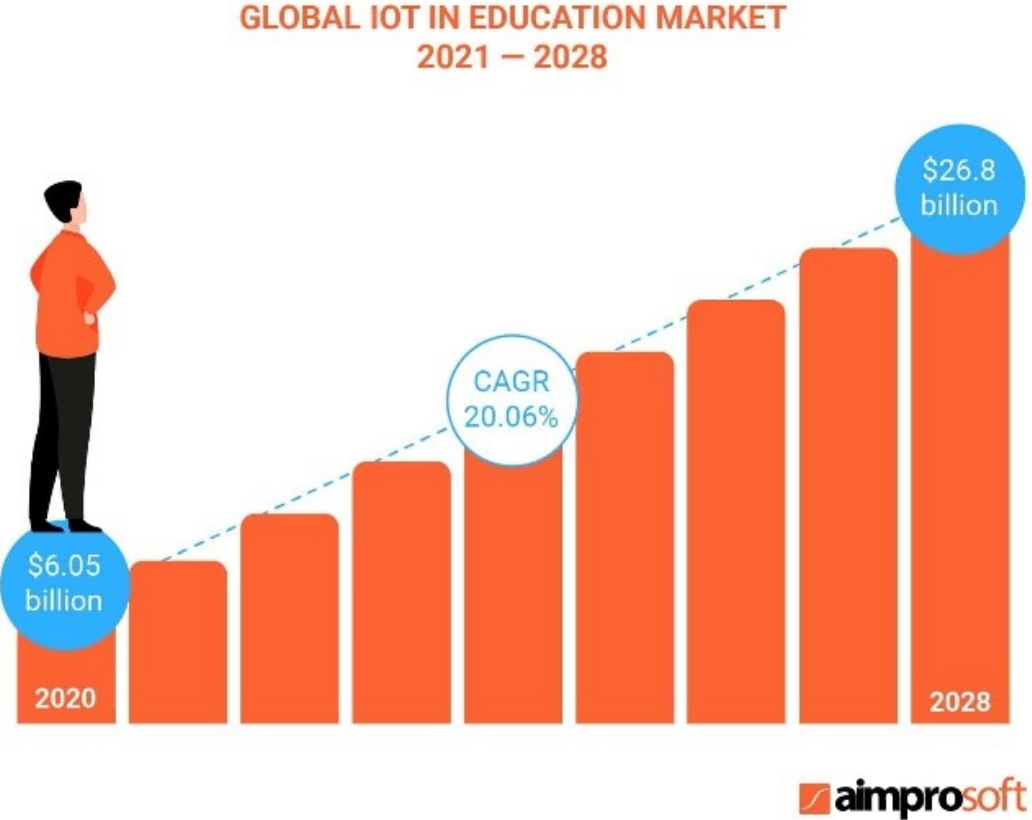


FIGURE 4. Source: Verified Market Research (2023)

- Arrange for a simple and mechanized structure for IoT integration. Hefty IoT systems contain thousands of sensors and equipment and manually managing them is a complex procedure. Also, it is prone to errors. Automated integration allows the infrastructure to dynamically recognize the devices and allocate them to locations that are appropriate in the protected network.
- Provide network resources appropriate for the IoT structure that works effectively. Lots of equipment of an IoT system offers critical information, which requires a specific level of quality service (QoS). For example, cases for education use require bandwidth reservation appropriate in an infrastructure efficient network to confirm reliable service delivery.
- Create a safe environment against cyberattacks and the loss of data. In fact, the devices and networked IoT sensors are highly prone to attacks and security is the key to mitigating risk of cybercrime. Security check is important on numerous levels, including the suppression of IoT networks themselves [27].

13 IoT increases school exposure and universities to cybercrime

The application and evolution of IoT in the transportation sector is leading to a blast of threats to cybersecurity because the multiplying of sensors and connected equipment dramatically enlarges the attack surface on a network. Particularly, IoT is sensitive because the makers of several IoT devices do not take required precautions for their safety. More so, many production companies do not visualize the modern security requirements. Therefore, the IoT systems are becoming the fragile link in security in establishments of education.

14 The Benefits of IoT in education in developing countries

14.1 Improved safety management system through deployment of IoT in education

The IoT network in education permits school supervisors to alter security plans by the use of beacons, badges, doors and the window sensors. The IoT system is extensively implemented by various educational institutions to develop programs for intruders, extreme weather any threats or any security threats. Both the teachers as well as students could easily interact with security personnel via the provided button over beacon.

14.2 Improving student involvement with IoT in education

The time teacher delivers lectures, he cannot always incite the students' concentration level. This is the time when the teacher can attract attention of the sleepy students with variations of lights. In addition, the real information gathered by (IoT) the Internet of Things can be used to foresee and scrutinize students' activities to develop an effective system of teaching.

14.3 Energy consumption is reduced by IoT in education

Lighting along with other amenities can be automated. For instance, lights are scheduled accordingly or can be connected with occupancy sensors. These sensors will automatically turn off when it senses that there is no one in the classroom. The efficiency of the building will enhance in this way and energy waste will be reduced, hence, resulting in cost savings.

14.4 Improved work efficiency with IoT in education

In a traditional set-up of an educational institution, particularly those schools that have relatively backward conditions, logistical tasks are not only boring but time-consuming as well. Implementing Internet of Things will reduce time as well as cost incurred over manual tasks like paperwork, money management and tracking of material.

14.5 Global connection exists with IoT in education

IoT systems connect and expose countries' educational system in schools and universities around the world. It provides a platform for interacting with the global systems hence, improving education quality [28].

15 Integrating IoT in education

15.1 Managing attendance

Beacons are found to be highly effective in improving the accuracy and efficiency of automated attendance. Everyone has their own badge, and their location is tracked in real time. As soon as they enter in the classroom, the system will be automatically updated with their location. Alongside, attendance management, beacons are also useful in managing and improving on-campus security. When the sensor detects movement in a prohibited area, there will be an alarm sound. In this way many schools detect invasion of strangers to avoid any mishap or tragedy on campus. More automated tasks eventually means teachers are in a position to focus more on lesson preparation.

15.2 Reduce on-campus traffic

Parking beacons can also be installed at school garage areas inclusive of cycle parking areas. When the car enters the campus, the driver will be informed by the system when a parking space is empty. Moreover, the location of the vehicle can also be traced on the application which means you do not have to find where the vehicle is parked. In addition to this, school buses can also be equipped with beacons, so as to keep parents informed as to when the bus will arrive at their doorstep.

15.3 Tracking of assets

School materials are an important asset. Tablets, laptops, educational materials, lab equipment and others can be monitored with locator beacons and motion detectors. Tags assure that the assets are in their right place and are being used correctly through transparent asset location. School procurement staff may also provide assets based on inventory count.

15.4 Energy monitoring

Being a densely populated place, daily expenditure on energy is never a small amount of money. Additionally, increasing concerns related to global warming necessitate reforms within the education sector so as to protect scarce resources of energy. With motion sensor, lights can be automatically switched on or off when there is no motion. Using all these facilities can also be monitored in real time by connecting it with a smart plug. The amount of power used by each device at a certain time can be monitored, and when any device is tracked to exceed the time limit, a signal in the form of alarm will be activated for notifying relevant employees.

15.5 Monitor facility usage

Through connecting motion detectors and occupancy indicators with the Internet, room equipment and use are accessible, particularly in spaces like computer labs and school libraries. Occupancy

status is easily accessible and arrangement is completed with the help of the IoT solution. Tracking this data allows those who manage the school to witness and report on how students are using particular spaces and resources.

15.6 Data acquisition and analysis

The needs of the students are the key for working towards increasing the rate of employment of schools. The conventional system of education has a very weak information flow and is not capable enough to adhere with the current development. Implementing IoT in education has the potential to improve educational programs by understanding student's behaviors and needs along with investing in assets and technologies related to it [29].

15.7 IoT future importance in education: what to expect

The IoT is swiftly shaping and growing in educational segment at a flourishing pace. Where some of the schools have practiced early adoption and are discovering the application of IoT solutions, there are other schools that are continuously investing in IoT technologies so as to determine the future shape of education. Although the education sector in developing countries are still not at the lead in the adoption of IoT systems, it is highly expected that IoT systems will be implemented widely in schools in the upcoming years.

References

- [1] M. Khan, O. Alhazmi, M. Javed, H. Ghandorh, and K. Aloufi, *Reliable Internet of Things: Challenges and Future Trends.*, Electronics **10** (2021), 2377.
- [2] J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami, *Internet of Things (IoT): A vision, architectural elements, and future directions*, Future generation computer systems **29(7)** (2013), 1645-1660.
- [3] B. Guo, D. Zhang, Z. Wang, Z. Yu, and X. Zhou, *Opportunistic IoT: Exploring the harmonious interaction between human and the internet of things.*, Journal of Network and Computer Applications **36(6)** (2013), 1531-1539.
- [4] L. Gartner, *Gartner Says the Internet of Things Installed Base Will Grow to 26 Billion Units By 2020.*, Gartner (20213).
- [5] K. Patel and S. Patel, *Internet of things IOT: definition, characteristics, architecture, enabling technologies, application future challenges.*, International journal of engineering science and computing **6(5)** (2016), 6122–6131.
- [6] M. Bhuiyan, D. Rahman, M. Billah, and D. Saha, *Internet of Things (IoT): A review of its enabling technologies in healthcare applications, standards protocols, security and market opportunities.*, IEEE Internet Things Journal **8** (2021), 10474–10498.
- [7] Y. Liu, C. Yang, L. Jiang, S. Xie, and Y. Zhang, *Intelligent Edge Computing for IoT-Based Energy Management in Smart Cities.*, IEEE Network **33(2)** (2019), 111-117.
- [8] W. Shi and S. Dustdar, *The Promise of Edge Computing.*, Computer **49(5)** (2016), 78-81.
- [9] A. Banafa, *IoT Standardization and Implementation Challenges.*, IEEE. org Newsletter. (2014), 1-6.
- [10] R. Khan, S. Khan, R. Zaheer, and S. Khan, *Future internet: the internet of things architecture, possible applications and key challenges.*, In Frontiers of Information Technology (FIT), 2012 10th International Conference **12** (2012), 257-260.
- [11] M. Abomhara and G. Koiem, *Security and privacy in the internet of things: Current status and open issues.*, International Conference on Privacy and Security in Mobile Systems (PRISMS) (2020), 1-8.
- [12] G. Akpakwu, B. Silva, G. Hancke, and A. Abu-Mahfouz, *A survey on 5g networks for the internet of things: Communication technologies and challenges.*, IEEE Access **6** (2019), 3619–3647.
- [13] R. Gupta and K. Jha, *A survey of 5g network: Architecture and emerging technologies.*, IEEE Access **3** (2015), 1206–1232.
- [14] J. Ramos and D. Shapiro, *Ambient Intelligence – the Next Step for Artificial Intelligence.*, IEEE Intelligent Systems **23(2)** (2018), 15-18.
- [15] J. Ploennigs, J. Cohn, and A. Stanford-Clark, *The Future of IoT.*, IEEE Internet of Things Magazine **1(1)** (2018), 28-33.
- [16] S. Lucci and D. Kopec, *Artificial intelligence in the 21st century : a living introduction (Second).*, Mercury Learning and Information (2023).
- [17] O. OECD, *Artificial Intelligence in Society.*, Computer Technology (2019).
- [18] M. Marjani, F. Nasaruddin, A. Gani, A. Karim, I. Hashem, A. Siddiqa, and I. Yaqoob, *Big IoT data analytics: Architecture, opportunities, and open research challenges.*, IEEE Access **5** (2017), 5247-5261.
- [19] S. Siemens, *Data-Driven Cities.*, Siemens.Com (2020).

- [20] J. Gubbi, *Internet of things (IoT): A vision, architectural elements, and future directions.*, Future Generation Computer Systems **29(7)** (2020), 1645-1669.
- [21] M. Gusev, *A new computing solution for IoT streaming devices.*, 40th IEEE International Convention on Information and Communication Technology, Electronics and Microelectronics **MIPRO 17** (2017), 387-392.
- [22] C. McKinsey, *The Internet of Things: Catching up to an accelerating opportunity.*, Internet of Things (2021).
- [23] S. Anbumani, *Digital marketing and its challenges.*, Airo International Research Journal **XII** (2017).
- [24] R. Market, *Verified Market research* (2021).
- [25] R. Karen, E. Scott, and C. Lyman, *The Internet of Things: An Overview Understanding the Issues and Challenges of a More Connected World.*, The Internet Society (ISOC) (2015).
- [26] D. Ramlowat and B. Pattanayak, *Exploring the internet of things (IoT) in education: a review.*, In Information Systems Design and Intelligent Applications, Springer, Singapore (2019).
- [27] Weber R., *Internet of Things – New security and privacy challenges.* Elsevier Computer Law and Security Review, 2020.
- [27] F. Yinan, Z. Pan, X. Jie, J. Shouling, and W. Dapeng, *Video Big Data Retrieval Over Media Cloud: A Context-Aware Online Learning Approach.*, IEEE Transactions on Multimedia **21(7)** (2019).
- [28] J. Burgess, P. Mitchell, and T. Highfield, *Automating the digital everyday: An introduction.*, Media International Australia. (2017).
- [29] U. Curtin, *Curtin University Advances Smart Campus Vision.*, Advances Smart Campus vision with Hitachi IoT Solution. (2017).