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# Internet of Things in Higher Education: A Study on Future Learning

Hanan Aldowah<sup>1,3</sup>, Shafiq Ul Rehman<sup>2</sup>, Samar Ghazal<sup>1,3</sup>, Irfan Naufal Umar<sup>1</sup>

<sup>1</sup>Universiti Sains Malaysia (USM), Centre for Instructional Technology and Multimedia (CITM), Penang, Malaysia

<sup>2</sup>National Advanced IPv6 Centre (IPV6), Universiti Sains Malaysia (USM), Penang, Malaysia

<sup>3</sup>Centre for Information System and Technology (CIST), Hodiedah University, Hodiedah, Yemen

hanan\_aldwoah@yahoo.com

**Abstract.** In the coming years, technology will impact the learning experience in many ways. Internet of Things (IoT) continues to confirm its important position in the context of Information and Communication Technologies and the development of society. With the support of IoT, institutions can enhance learning outcomes by providing more affluent learning experiences, improved operational efficiency, and by gaining real-time, actionable insight into student performance. The purpose of this study is to find out the potential of IoT in higher education and how to maximize its benefits and reducing the risks involved with it. Further efforts are necessary for releasing the full potential of IoT systems and technologies. Therefore, this paper presents a study about the impact of IoT on higher education especially universities. IoT stands to change dramatically the way universities work, and enhance student learning in many disciplines and at any level. It has huge potential for universities or any other educational institutions; if well prepared to ensure widespread and successful implementation by leadership, staff, and students. IoT needs development where universities can lead. Academics, researchers, and students are in a unique place to lead the discovery and development of IoT systems, devices, applications, and services. Moreover, this paper provides an evidences about the future of IoT in the higher education during the next few years, which have offered by a number of research organizations and enterprises. On the other hand, IoT also brings tremendous challenges to higher education. Hence, this paper also presents the perspective on the challenges of IoT in higher education.

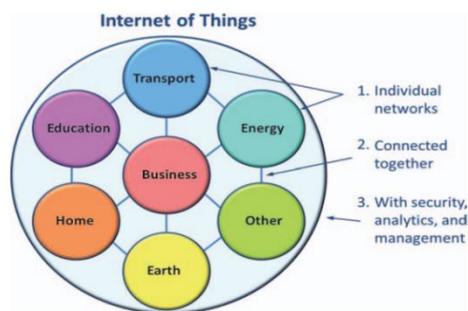
## 1. Introduction

Internet of Things (IoT) is the transformation process in numerous aspects of our daily life. IoT technologies differ from previous innovations as they are ubiquitous, and encourage solutions to be intelligent and autonomous [1]. Advances in the IoT are a major strategic technology trend [2]. Ubiquitous sensors and the ability to bridge the gap between the physical world and the machine world were perceived as the conceptual framework for the new learning model. The thinking behind this great paradigm shift is the ability to embed sensors into any object and use Machine-to-Machine (M2M) communication to connect billions of objects/devices to the current Internet infrastructure. The entirety of the physical world is coming online rapidly.

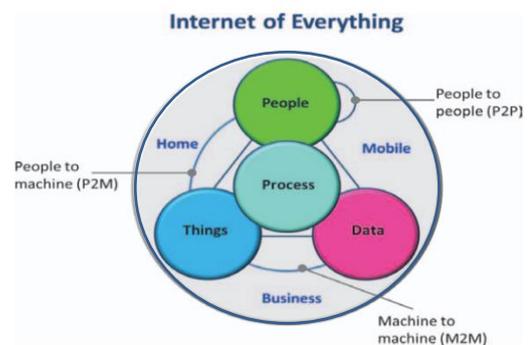


IoT is developing quickly and becoming an increasingly growing topic that creates excitement and anxiety around the world [3]. There are plenty of indications showing that the IoT will to change many sectors, including higher education institutions, especially universities. Now, universities has an opportunity to lead the technical development and the innovations models for the IoT, and to build the leaders of the IoT into the future, as well as to address the TIPPSS risks which stands for Trust, Identity, Privacy, Protection, Safety, and Security related to the IoT.

The IoT is a global physical network which connects devices, objects and things to the Internet infrastructure to communicate or interact with the internal and the external environment as illustrated in Figure 1, and for the purpose of exchanging information through the information sensing devices according to specific protocols. Thus, IoT is enabling connectivity for anything and for anyone to be networked around the world anytime, and anywhere using any network or any service [4] to achieve the goal of intelligent identifying, tracking, and managing things [5]. It is an extension and expansion of Internet-based network, which expands the communication between human to human (H2H), human to things (H2T) or things to things (T2T) [6] as presented in Figure 2.



**Figure.1.** IoT viewed as a global network.  
(Source: Cisco IBSG, April 2011).



**Figure.2.** Internet of everything  
(Source: Cisco, April 2011).

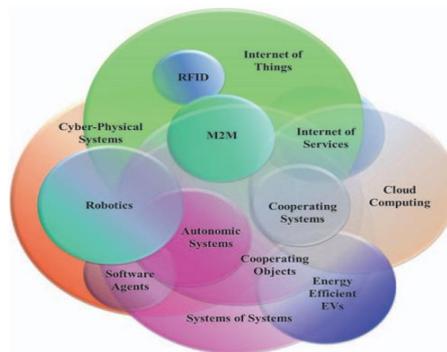
A number of research organizations and analysts have predicted about the future of IoT and its potential impact on the Internet: billions of physical devices, all over the world, that have digital sensors and are interrelated by leveraging any network. According to the research conducted by Juniper [7], an estimated 13.4 billion devices were connected in 2015, which represent more than the total of population on the earth at the time, and this number is expected to triple to 38.5 billion devices by 2020. The opportunity of interacting with lots of everyday objects connected to the Internet allows individual to access unlimited information anytime and anywhere. This vision opens a new horizon of ideas and developments that is already being considered by research scholars and academics.

The IoT vision is grounded in the belief that the firmly fixed advances in microelectronics, communications and information technology we have witnessed in current years will endure into the predictable future [8]. Applications for the IoT are already being leveraged in sectors like healthcare and customer service. Now, universities and schools are joining the party. Some of the ways the IoT can benefit education may be manifest, while others are not as obvious. So this paper will present the biggest implications for connected devices in higher education and how they could shape the learning for the next generation.

The future of universities is not about using and employing the available technology. It is about how universities will adapt to the changing needs of the future knowledge worker, the future of work, and the economy. This paper presents an overview of IoT in higher education institutions, especially in universities and takes a look at several emerging trends that are evolving higher education, and explore the potential impact of IoT and the future of the IoT in higher education. In addition, exploring some of IoT challenges regarding higher education sector.

## 2. Basic Components of IOT

The IoT is empowering technology researchers to develop smaller and more affordable wireless systems that consume less power and can be integrated into almost any type of device [9]. There are three IoT components which enable seamless connections which are: Hardware: made up of sensors, actuators and embedded communication hardware, Middleware: on demand storage and computing tools for data analytics, and Presentation: novel easy to understand visualization and interpretation tools which can be widely accessed on different platforms and which can be designed for different applications [10]. There are a number of potential approaches for introducing low-power communications to an IoT node, ranging from purpose-designed protocols such as ZigBee to low-power variants of Bluetooth, Wi-Fi and NFC. Although Wi-Fi is the most popular form of integrated wireless technology and the best power-per-bit transmission efficiency, IoT enhances other formats including Radio Frequency Identification (RFID) technology which is used throughout business, industry and personal technology systems and enables design of microchips for wireless data communication [10]. Some of this technology can add wireless sensor capabilities (WSN) to any type of device, like FitBit wearable fitness trackers, and books.



**Figure 3:** Technology convergence.

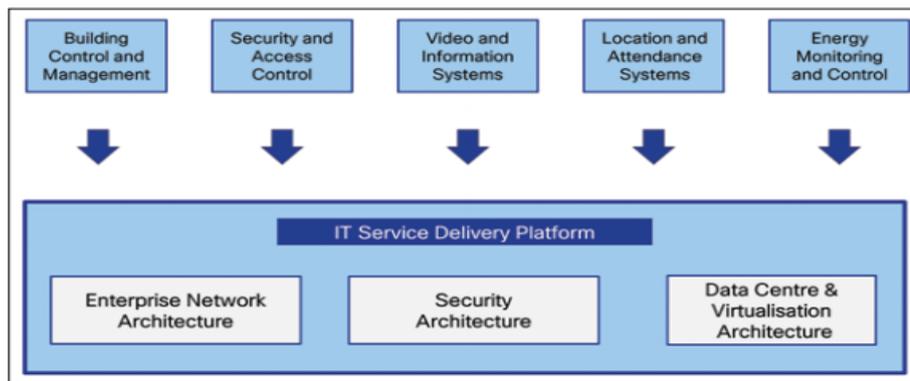
**Source:** (Friess, 2013)

## 3. Concept of Digital Campus

Digital Campus System is an important platform for students to get all kinds of information [11]. New technologies are also affecting other areas of campus administration. There is an increasing demand for higher education institutions, especially, universities to digitize their content and activities, and adapt their methods to allow academic and researchers to work effectually in a digital environment [12]. A well designed physical campus, completely integrating technology, is fundamental for building the brand of digital university by enhancing the student experience, and providing the appropriate settings and facilities for teaching, learning and research. It promotes, supports and encourages lifelong learning [13]. A digital university must have the technology that enabled teaching and learning, and empower collaborative research. All contemporary digital threats can be faced by universities if they compete, however few have the vision, flexibility, platforms, or appropriate leadership, to put in place the strategies to ensure that they can innovate, or react to marketplace conditions.

Within a digital campus, technology can reduce operational costs, improve security, and offer tools for researchers, academics, students and staff. These benefits provide real value to university operations and developments, the experience of students, and researchers. The digital campus comprises two main components. Firstly, it reuses the IT Service Delivery Platform – end-to-end

infrastructure to provide network connectivity, mobility and security for all applications and services across the campus. Secondly, it includes a large number of Internet of Things (IoT) applications operating over the platform system to support the professional of the university, enable teaching and learning activities, and enhance student's experience. According to Cisco -"Digitizing Higher Education To enhance experiences and improve outcomes"- IoT applications differ from conventional network applications as they support sensors and sensor data, rather than users and user data. IoT applications for the digital campus include five main categories: Building Control and Management; Security and Access Control; Video and Information Systems; Location and Attendance Systems; Energy Monitoring and Control. as shown in Figure 4:



**Figure 4:** IoT Applications for the Digital Campus

**Source:** Cisco- Digitizing Higher Education To enhance experiences and improve outcomes.

The wireless network has a main role to play within the digital campus, thus must be designed to meet the high demands of a modern university.

In addition, IoT reform and change the teaching and learning in the campus, for example, the IoT in the training of the same sight, making the teaching space, training venues, sports venues, learning dormitories, restaurants and students across the campus of IoT, making the campus to train students anytime and anywhere, can become a physical, mental, and skills place to acquire a full range of learning and training. This will lead colleges to become ubiquitous learning and training [14].

#### 4. Impact of Internet of Things on Higher Education

The IoT is going to affect every part of society at some point in the near future. Higher education institutions in general, and universities in particular, can work across disciplines and lead the progress of the IoT technologies, business models, ethics, and leaders of the IoT enabled economy of the future. For instance, university instructor of computer science and engineering are directing IoT labs for the development of IoT technologies. In addition, Informatics College can teach how to leverage the sizes of IoT data, with TIPSS. Also, they can work with business colleges to set and design IoT courses to create new business models. Medical colleges can empower the Internet of Medical Things as well as, Law colleges can teach IoT ethics, privacy, and policy. According to Zebra technologies, as higher education institutions commence to develop and leverage solutions such as radio frequency identification (RFID) and cloud computing through IoT technologies, they will be able to analyse and manage Big Data.

The IoT is not just a technology update and development within the industry, but can lead to expand the change to the whole society including higher education institutions. IoT will lead the change and reform the higher education institutions. According to [14], IoT will lead

to changes in educational technology, reform the education, change in teaching, change in learning, management of change, experimental and practical changes, changes in campus, teaching resources changes and others.

With the development of IoT, the prospective application in higher education lies in the three aspects: students' progressive evaluation, integration of current teaching platforms and development of educational middleware [15]. This change provides increased convenience for students, and makes the teaching process more effective for instructors and professors. The flow in connected devices and technology means that instructors and professors can focus on the actual learning that is more useful to the students rather than perform the routine task.

In addition, IoT has the ability to increase the learning experience by providing for real-time and actionable insights into student performance. Nowadays, students particularly in university are gradually moving away from textbooks to new technologies such as tablets and laptops. The advanced e-learning applications allow students to learn at their own pace and have an identical learning experience in classrooms and homes [16], which rises progression and satisfaction rates as well as instructors can deliver one-to-one instruction and persistent student assessments [17]. Moreover, through IoT technology, professors can collect data about students' performance and then determine which ones need more care and attention. This data analysis also helps instructors accurately change plans and methods for future classes. Additionally, connected devices can allow instructors to do dynamic classroom. Interventions as well as logging attendance will be simplified if students have a wearable device that tracks ECG patterns. Furthermore, these devices can redirect a student's attention by giving a warm up activity and exercise to do on their own devices. Also, EEG sensors can be used during courses to monitor students' cognitive activities.

This vision and understanding give stakeholders with a view of students, organization, and financial assets. This asset intelligence enables organization to make informed decisions in order to enhance student knowledge and learning experiences, operational proficiency, and the security of campus. According to Zebra technologies (2015), by enhancing asset intelligence, educational institutions can enhance outcomes by adding values in some areas include: Enhanced Learning Experiences and Outcomes, Improved Operational Efficiency, Safer Campus Designs.

Moreover, outside of the classroom, universities can use connected devices to monitor their students, staff, resources and equipment at a reduced operating cost [18]. Furthermore, the growth of mobile technology and the IoT enable universities to improve the security of campuses, enhance access to information and applications at anytime from anywhere, and keep track of main resources [10]. IoT is changing the student learning experience besides facilities management by connecting individual, data and things.

## **5. Future of IoT in Higher Education**

Universities have long realized the ability of technology to disrupt teaching, learning, and assessment. Furthermore, technology disruption is fundamental if a modern university is to distinguish its student offer, so increasing admissions, improving retention, and delivering desired outcomes. But preparing students to be confident for the world of work is complex. It requires strong academic leadership, access to a high quality curriculum and content, and the exposure of students to the effective use of new technology. With the development of IoT, many institution of higher education have started to focus on the related technology and application of the IoT [9, 19]. This attempt is also used in university [20]. The Internet has deeply rooted itself into colleges and universities, and e-learning has become common practice in most universities systems [16]. Although it is not an obvious application of the IoT, however, education is on that list [10] and the applications of the IoT in universities are numerous, and the implications for this are massive. IoT will allow for better operational efficiency in all learning environments. IoT can support classroom instruction by improving learning setting, enhance learning resources, improve methods and techniques of learning, raise management

efficiency, and save management costs. The resources available for learning on devices, like e-books, are more engaging and interactive. However, there is a constant need for new technologies for learning process, for instance, high-speed wireless networks with the bandwidth for streaming audio and video lessons.

According to the Citrix 2020 Technology Landscape Report (2015), in the next five years, IoT technology will enhance the learning experience in different ways. Learning experience will continue to become more virtual, students will consume knowledge and learning in new ways, and classrooms will be better equipped for learning. Eventually, learning will become an amazing experience for instructors and students with knowledge accelerating while bringing new ideas and solutions around the world. As well, students are prepared for the future of work and expectations at the workplace of the future.

Technology will always have a place in all educational disciplines [21]. IoT also has many opportunities for Science, Technology, Engineering, and Mathematics (STEM) disciplines, such as computer programming and physical computing. It is easy to foresee how IoT capabilities can be used in STEM disciplines, robotics, and anything having to do with collecting specific data. It is all in the potential of the IoT. However, ultimately the educationists need to be able to identify the right technology and integrate it properly in the classroom for learning to evolve. Although main IoT technologies are so far unclear, the point certainly is that a lot of contents are the outcome of new development phase. Considering the demand of more professional research, setting the IoT major is relative easy and applicable for graduate students. However, for undergraduate students, they still need a wide range of basic courses, so it is not easy to set IoT major independently like other majors at present. New training methods shall be explored for undergraduate students [22]. Different colleges have to explore the appropriate approach according to their own characteristics. The system approach and courses content need to be progressively established and improved. Since IoT is achieving the unity of the virtual world and the physical world, many new training methods and cross-cutting areas will be generated in the future [3].

Moreover, the future IoT economy can be shaped by experts and leaders in higher education sector and by educating the students [23]. The development within higher education systems will visualize, improve, and lead the new technology innovations. Therefore, higher education sector must work with business and industrial sectors to shape and build the future of an IoT-enabled economy. Furthermore, higher education sector, especially universities, have the opportunity to lead the future of IoT technologies by designing courses for technical and business leaders and by facilitating students and researchers work to build new business methods that leverage IoT technologies in a multidisciplinary way.

In 2016, a workshop conducted by IEEE, National Science Foundation (NSF), and Internet2, entitled "End to End Trust and Security for the Internet of Things", and followed by an IEEE Experts in Technology and Policy Forum, the experts and participants asserted that the IoT needs innovation and development which researchers, professors, academics, and students in universities and higher education sector are in a unique place to lead the innovation and development of IoT devices, systems, applications, and services. Also, they emphasized that new platforms and ideas across disciplines must be developed and discovered to solve many problems and issues that we are facing nowadays. In addition, IoT and data analytics tools can be leveraged to develop and improve effectiveness and competences on campus and across societies, to improve information capture, to address security and privacy issues, to minimize the energy use, and to analyze data and provide actionable insights and understanding to develop and enhance health sector. To build this system sight, working across skill sets and disciplines are required. Furthermore, academics and research scholars can build end-to-end TIPSS solutions for the IoT as well as they can build IoT devices, and services with a "defense in depth" strategy, adding in security at the hardware, software, firmware, and service levels.

## **6. Challenges of IoT in Higher Education**

IoT brings tremendous challenges and opportunities to higher education. The unique growth of ubiquitous computing, developing IoT technologies such as cloud computing, and big data and analytics are helpful not only in improving the core values of teaching and quality of research but also developing an IoT society and encouraging a new digital culture. With increasing online degree opportunities and seamless access to instructional content in both structured and unstructured formats, the IoT leads digital momentum into higher education institutions. IoT is a dramatic shift in the traditional instructional paradigm while integrating broader disciplines, including social science, to enrich the value of big data available from social media. Some of the IoT challenges in higher education sector include:

### *6.1. Cloud Computing*

Many universities are using hybrid cloud as their enterprise architecture for hosting IoT applications. The combination of millennials, the most tech-savvy students in the universities, as well as the rise of tablet and mobile technology, has opened new methods to increase the effectiveness of enterprise architecture, instructional technologies, research and learning environments. With ubiquitous computing, the cloud provides seamless connections and services to information technology services. Presently, enterprise architecture in many higher education institutions depend on hybrid cloud infrastructures with computing platforms on private clouds, while enterprise and instructional applications gradually move to public clouds. Enterprise architecture in these institutions need reduce latency time because of the demand for content in instructional technologies, the huge increase in audio and videos for instructions, and the need for active enterprise networks.

### *6.2. Instructional Technologies*

The growing use of learning management systems LMS like Moodle and Blackboard is creating massive amount of structured and unstructured data such as audio and video content. Sophisticated electronic schoolrooms equipped with lecture capture systems and web streaming provide an opportunity for students to access instructional contents on demand at any time [9].

### *6.3. Mobility Applications*

IoT applications are being increasingly used to integrate mobile learning applications and for assessment and grading systems. The ideal application can assist students to benefit from learning resources, manage assignments, and work on tasks. Instructors also use some of these applications to teach highly specialized concepts, complex physical, scientific simulations, and social topics.

### *6.4. Security and Privacy*

The implementations of IoT technologies present new and unique security and privacy challenges and issues. Addressing these challenges and issues to ensure security in IoT devices and services should be a fundamental priority [8]. One of the fundamental criteria for IoT is the need to include effectual and trustworthy privacy and security mechanisms [24]. Higher education is vulnerable to the security and privacy of the IoT ecosystem.

Even though there has been further momentum to deal with the security of the IoT infrastructure, there is still no strategy to identify business risks associated with data breaches. Higher education sector need to develop standards to secure IoT applications. As higher education creates millions of future workers, it has to embrace IoT platforms and systems even with the challenges of IoT financing, evolving digital educational pedagogy, training, and interdisciplinary research. In addition, IoT applications must engage the future workforce morally and ethically to address cyber security issues as society depends more on IoT applications. Therefore, a collaborative method to safety and security

will be required to develop solutions in effective and appropriate way to face IoT security challenges. Furthermore, the full potential of the IoT depends on strategies that consider people's privacy. Therefore, to fulfill these opportunities, there is need to develop new strategies that consider an individual's privacy choices and expectations, whilst still promote innovation in new technologies and services [8].

### *6.5. Research Computing*

Higher education continues to benefit from IoT integration. As the cost of hardware reduces, interdisciplinary research has gained momentum in the last years. In addition, with the availability of big data, even smaller universities can increase their interdisciplinary research footprint and put in high performance computing (HPC), big data platforms, and analytics. STEM education has seen the necessity of identifying broader collaboration with IoT ecosystems by using sensor technologies, Unmanned Aerial Vehicles (UAVs) and microcontrollers. Engineering laboratories use audio video technologies, UAV, Raspberry Pi and open source systems (OSS) that are driving innovations and enhancing learning processes in engineering projects. Social science researchers intrigued by the plethora of big data generated by social media and omnipresent computing are constantly using distributed computing platforms such as HPC, GPU clusters, Hadoop clusters and big data analytics to improve IoT research.

### *6.6. Quality and Ethics*

The quality of learning both online and on campus and the rising cost of higher education has been intensely debated in latest years. The IoT offers unique opportunities to deliver digital courses. However, it also introduces challenges to maintain the quality of instruction and evaluation of students' work. IoT educational applications need tools and technologies for instructors, professors and the scientific community to improve the quality of research and address ethics issues within higher education.

### *6.7. Financing*

The cost of information technologies continues to increase every year as content and an application. These application stacks continue to grow both horizontally and vertically on instructional technologies, research computing and enterprise technologies. Alongside the information technology and laboratory fees, most universities do not have a strategy for sharing costs and identifying the total cost of ownership for an IoT infrastructure. Higher education must come up with new ideas to finance an information technology infrastructure and services.

## **7. Conclusion and Future Work**

With the advancement in technology i.e. Internet of Things, universities can resolve many challenges such as; keeping track of essential resources, develop access to information, build smarter plans, and design safer campuses. IoT systems have tremendous potential to bring significant values to higher education by engaging and motivating the students and staff, and to increase speed of learning. The purpose of this study was to find out the potential of IoT in higher education and how to maximize its benefits while addressing its challenges and reducing the risks involved with it. Therefore, our future work will be to focus on IoT implementation in higher education.

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