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# Smart Campus Using IoT with Bangladesh Perspective: A Possibility and Limitation

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***Abstract*: *The concept of smart classroom has been around for quite a long time and a lot of work still in progress to facilitate teaching-learning environment in more productive and intuitive way. This SMARTness did not limit itself into a single classroom, rather it extended itself to make the whole institute campus smart by automating facilities and access to individual entity. This move gained much pace by the introduction of the concept of Internet of Things (IoT). IoT is not a new concept, but it actually formalized a process where an Object itself has ability to sense its environment, act (optionally) according to sensed data, and finally and more importantly, communicate this data to a remote entity over a network. This way an Object becomes a smart entity which can literally be applied to any field or context that is only limited by the imagination. Smart campus, smart city, smart classroom, and much more Machine-to-Machine (M2M) applications are examples of IoT. In this paper, IoT enabled smart campus environment was explored based on existing literatures and different applications. Then current state of a university campus in Bangladesh, Hajee Mohammad Danesh Science and Technology University (HSTU), was explored and finally, possibility and opportunity of applying IoT enabled smart classroom, laboratory, library, and buildings for the context of HSTU was investigated and necessary recommendations were suggested in order to avail the smartness in HSTU university campus.***

***Keywords*: *Internet of Things (IoT), Machine-to-Machine (M2M), Smart classroom, smart campus, HSTU.***

## I. INTRODUCTION

The concept of IoT was new, rather its working mechanism was around by many other names - Macihne-to-Machine (M2M) is one of them. Lots of M2M application exists including smart prepaid electric meter and GSM module enabled different utility usage monitoring application. The core idea was a smart sensor which senses something from environment and communicates over a network to a remote entity. However, the introduction of IoT is welcome with the vision that it will formalize lots of areas related to this M2M process.

### *A. The Concept of IoT*

Kevin Ashton firstly proposed the concept of IoT in 1999 where IoT was referred as uniquely identifiable inter operable connected objects with radio-frequency identification (RFID) technology. But the definition of IoT is still evolving and yet to mature. [1]-[3]. IoT was identified as a dynamic global network infrastructure that is capable of self-configuration based on standards and interoperable communication protocols. Things in IoT could be physical or virtual which have identities and attributes and are capable of using smart interfaces and communicate with an IP network. [4]-[7] IoT can be defined as a collection of connecting devices that are uniquely identifiable by near field communication (NFC) techniques. [8] IoT can be defined in terms of its two main keywords 'Internet' and 'Things' such that Things (sensor based connected devices) sense data and communicate over global network to send data for further processing and decision making. [9],[10]. Despite the argument on the definition of IoT, it has been discussed widely and corresponding technologies have been rapidly developed by various institutions. [1],[3],[11]-[13] Intelligent sensing and wireless communication techniques have become part of the IoT and new challenges and research horizons have emerged. [14],[15]. The International Telecommunication Union (ITU) discussed the enabling technologies, potential markets, and emerging challenges and the implications of the IoT [12],[16]. The evolvement of IoT can be illustrated by several phases as shown in Fig. 1. The IoT is initiated by the use of RFID technology, which is increasingly used in logistics, pharmaceutical production, retail, and diverse industries [17]-[20].

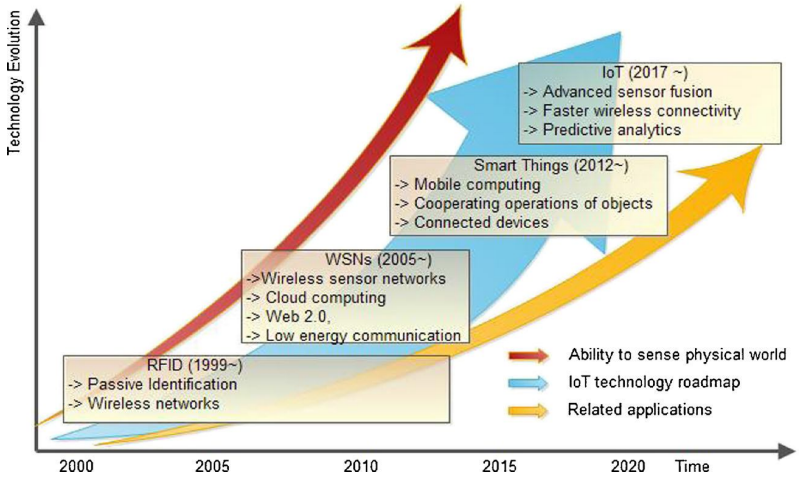


Fig. 1 Evolution of the IoT [21]

*B. The Internet of Things Application Areas*

The IoT can be applied in a whole range of domains as follows [22]-[24]:

1) *Medical and Healthcare Technology:* The IoT has diversity applications in the medical sector. These may include wearable things to detect verities of reaction to drugs in patients. IoT is also used in the monitoring and measuring of important functions of the body such as temperature, blood pressure, heart rate, cholesterol levels and to stimulate the heart muscle in case of a heart attack and various disease.
2) *Retail, Logistics and Supply Chain Management:* Implementing the IoT in retail, logistics and supply chain management has its own greater advantages. IoT can can be used to track the present items in real-time to alert when to make new orders. Fast payment solutions can be offered through tag reading check-out points. IoT offers the opportunity to trace goods across the supply chain, so that recalls can be issued when quality problems arise.
3) *Transport:* The IoT offers a number of solutions in transport sector. Some of the application areas for IoT in transport includes: Toll systems, screening of passengers and goods on aeroplanes to meet security requirements, monitoring traffic jams, and automated tracking of passengers and luggage.
4) *Insurance:* In car insurance, electronic recorders are placed in cars to record speed, acceleration and communicate the information to the insurer to assess the risk.
5) *Energy:* The Bits to Energy Lab, a joint research initiative of the ETH Zurich and the University of St. Gallen in Switzerland, through its Amphiro project have developed a smart water meter that provides feedback on water consumption directly at individual faucets or shower heads. The device captures flow rate and temperature and derives the amount of water extracted, energy used and carbon dioxide emitted.
6) *Information Security:* The advanced research on information security and privacy project (ARES) which is funded by the Spanish Ministry of Science seeks to bring security to the information society while preserving individual rights. It focuses on three intertwined application scenarios, that is, ubiquitous computing with emphasis on wireless sensor networks and RFID, protection of critical information infrastructures and secure electronic commerce and digital content distribution, while tackling different tactical challenges in the areas of cryptology, smart cards, personal identification and biometrics, access control and authentication, network security and trust generation.
7) *Home Automation:* As cheap wireless applications become abundant, the range of applications broadens. For example, smart metering is become popular for measuring energy consumption and transmitting the information to the energy provider. Sensors for temperature and humidity provide the data to automatically adjust comfort levels in a room.
8) *Environment Monitoring:* Wireless devices increasingly used in green-related applications and environmental conservation are a promising market in the future. Remote monitoring of forest fires, possibilities of earthquakes, potential floods and pollution reduce environmental risks. The wireless industry offers the opportunity to monitor petroleum personnel in critical situations, the tracking of containers and the detection of gas and oil leaks as a way of reducing the risk of accidents.

9) *Manufacturing:* By linking items with embedded smart devices or through unique identifiers that can interact with an intelligent supporting network infrastructure, production processes can be optimized.
10) *Agriculture:* During outbreak of disease, real-time detection of the movement of animals through RFID tags becomes handy. To improve the efficiency of agricultural production, agricultural mechanization is a key measure.
11) *Telecommunications:* The IoT creates the possibility of merging different technologies such as Global System for Mobile Communications (GSM), Near-Field Communications (NFC), Bluetooth, Global Positioning Systems (GPS), sensor networks, etc to create new services. The border between IoT and telecommunications blurs in the long term.
12) *Education:* IoT can be used in various part of education sector. Starting from taking attendance of the students, educational resource referencing, digital note creations, distribution, sharing etc. learning suggestion, and evaluation IoT can play a vital role in teaching-learning mechanism. Since IoT is connecting already existing network devices with newly evolving smart things is creating a large scope of usage in education.

For example, at the University of Illinois, QR codes across campus lead students to videos, maps, and even the school's Facebook page and Twitter feed, and Northern Arizona University uses RFID chips embedded in student IDs to take attendance, which counts toward students' grades. Textbooks: QR codes are starting to show up in textbooks. Students can use their smartphones to scan these codes and access additional resources, assignments, and feedback. [25]

## II. SMART UNIVERSITY CONCEPT USING IOT

Smart university doesn't have a formal and broadly accepted definition, the main concept is to develop a university campus using IoT that utilizes the resources efficiently, deliver high quality services and security to the campus community, while the operational cost gets reduced. Smart University can bring a number of benefits such as: provide an interactive environment for students and faculty, promote smart energy and waste management, bring effective surveillance system and real-time incidents warnings, automate maintenance, efficient parking system and provide secure payments systems. [26]

### *A. Needs of Smart Campus*

A university campus is defined like a small world where everyday thousands of students, teachers, officers, visitors are present hare. Monitoring and maintaining all those peoples with their details and reporting frequently are not possible all the time. But in a smart university campus using IoT everything not, but many problems can be solved. It is only possible for the use of improved sensors technology. "The Internet of Things (IoT) will change everything, exercises and protests from easy to the most perplexing, and why not, even us people. Other than regions as business, transportation, vitality, medication, horticulture and others, the Internet of Things will likewise have a noteworthy implication in education." [27]

### *B. List of IoT Enabled Services in a Smart Campus*

All possible IoT enabled services in several sectors of a smart campus are describe below. [28]

1) *Smart Iot Enabled Classroom:* Classrooms are well decorated by new learning technologies and devices which make it possible for learning to any time to anywhere for students.
2) *IoT Based Hotspot For Campus:* Most of the learning point or collaborative point of a campus are connected with a network under a IoT based hotspot, which are easily accessible for student.
3) *Smart Inventory*: Each piece of component (CPU, printer, scanner, copier ETC) can have an associated bar code which represents inventory number and a QR tag. Using a device connected to the internet with a barcode reader this equipment can be identified with a barcode reader this equipment can be identified & it can be able to display all associated information.
4) *Smart Parking:* Monitoring of the university's parking system and finding details information and current position about the vehicles of the university for proper utilization.
5) *Automated Street Light:* A collection of electric lights are used in a university campus which consume a lot of electricity. Automatically sensor light adjusts the electric lights based on the data sent by an external sensor, which will reduce electricity consumption.
6) *GSM Based Alrets:* GSM based alert system send alerts to the authority if any unauthorized persons or unauthorized task occurred in the campus.

7) *Garbage & Waste Collection Bins Overflow Alert System (GSM/ZIGBEE):* Every campus is full of crowds. So, there must be a huge of waste every day which overflowing the garbage bins or dustbins placed at campus places. It creates unhygienic conditions for people.
8) *Water Flow Management and Automation:* Water Flow Meter maintain targeted irrigation that is measured and mindful based on moisture condition in soil.

### C. Type Of Sensors Used in Smart-Campus

Every sectors or area of a smart campus using IoT are connected with Sensors and new technologies which can be sent data or report each and every time under several conditions for take necessary step for the identified conditions. Some of the related sensors are given below. [28]

1) *Temperature:* Thermistors, thermocouples, RTD's, IC and many more.
2) *Pressure:* Fiber optic, vacuum, elastic liquid based manometers, LVDT, electronic.
3) *Flow:* Electromagnetic, differential pressure, positional displacement, thermal mass, etc.
4) *Level Sensors*: Differential pressure, ultrasonic radio frequency, radar, thermal displacement, etc.
5) *Proximity and Displacement:* LVDT, photoelectric, capacitive, magnetic, ultrasonic.
6) *Biosensors:* Electrochemical, surface Plasmon resonance, Light addressable potentio-metric.
7) *Image:* Charge coupled devices, CMOS.
8) *Gas and Fire:* Semiconductor, Infrared, Conductance, Electrochemical.
9) *Others:* Moisture, humidity sensor, Speed sensor, mass, Tilt sensor, force, viscosity.

## III. SMART CAMPUS: E-LEARNING APPLICATION USING IOT

### A. Smart Classroom With Iot

Traditional University with traditional classroom has blackboard, projector connected with PC, speakers etc, this type of classroom does not able to record their activity in any form. However, in smart university with smart classroom with IoT can do records all of the teaching & learning activities in a classroom through any enhanced devices. These recorded activities help all the learner even those who do not attend in the classroom.

"New learning technologies and mobile devices make it possible for learning to take place at any time, at any place, and at any place that the learner desires." [29] Because of new technologies used and mobile devices, learning take place anytime, anywhere, subject's data, teaching of high profile Professor's Lecture of different university reaches out any corner of the world.

"IoT leverages advances in electronics, enabling the development of smaller, reduced power, and most importantly offering less expensive wireless systems that can be integrated in almost any type of device. IoT leverages other connectivity technologies like Wi-Fi, ZigBee, NFC, RFID & Bluetooth." [30]

IoT uses various sensors and technologies connected through a network for making grouping system under common network.

### B. IoT Devices for Smart Classroom

Every Device's and new technology enhancement using microchip in performance plays an imperative role to transform classroom into smart classroom. [33]

1) *Smart Whiteboard using IoT:* Smart whiteboard setup is the main device of a smart classroom. It plays the role of a hub of all devices to get connected in single point of IOT sources.
2) *Standard Communication Techniques for New Model Setup:* Standard Data and communication flow setup between all data collection sources.
3) *Smart Classroom Monitoring:* Admin can monitor all activities of classroom and smart whiteboard can updates & synchronize with e-leaning system.
4) *Collaborating Classroom using New Model Setup:* Amalgamating multiple smart whiteboard from different locality of classroom to create collaborate learning environment by using smart classrooms.
5) *Energy Consumption:* IoT device's and sensors are used for more energy consumption while devices are in ideal state.
6) *E-Notes Management :*Classroom lectures are collected from smart board to share using e- learning application.
7) *Audio Management :* Classroom lectures audio recording are recorded by audio recorder and shared in cloud.

8) *Automation of Subject's Notes Sharing:* Platform used to share subject notes and audio record using admin activities in spite of that notes shared through automation activity.
9) *Interoperability in the Internet of Things:* The Smartness of Internet depends on Internet of Things. One Smart board things connected to multiple classrooms for sharing notes resources. Interconnection between several devices and things under of a common network its interoperability depends.
10) *Live Chatting:* In a smart classroom need live chatting options for external learner. Through this one can share their opinion at the class from outside.

### C. Outcomes using IoT in Classroom

Internet of things helps in multiple way to use in learning process. Encircle factor like easy way to capture data, storing of data, manipulate it, assessment of students, avoiding delay of transmission, frequency of usage. Etc.

"The Internet of Things doesn't function without cloud- based applications to interpret and transmit the data coming from all these sensors." [31] It reflects the importance of using cloud with IoT technology. This architecture depicts the same note sharing data storing in cloud to synchronize with IoT Tower sensor. [33]

### D. Importance of using IoT enabled Smart Classroom for E-Learning Application

IoT plays a very important role in every sector of our modern life. The overall purposes of IoT in a smart classroom for e-learning are described bellow [33]:

1) *Easy to Share and Access:* All class lecture notes and audio records are share with outside learners using smart classroom by admin easily. Every student from inside or outside of the class can access data any time. It widely creates a great impact on learning circles.
2) *Collaborative Learning can Achieve in Classroom Environment:* Smart classroom allows us to create collaborative learning environments in classroom with more number of students in different classroom in different region virtually.
3) *Improves Opportunity for Learning: Using* IoT enable smart classroom and video conference one student can learn any topic from top Professor's Lecture from well-*esteemed organization* "Potential to extend the reach of effective teachers" [32]
4) *Increase Competitiveness between Local & Global Students* Local students of any university can have direct competition with world-wide students in all form of activities.
5) *Easy to Setup Unified Learning Environments* Sharing classroom with one region to another place in the world makes easy to give unified learning classroom with the different set of students from an entire world.
6) *Enhances communication* With the help of IoT Device's and new technology in a Classroom, It enhance teachers and student communication from anywhere any time. Student can participate in a class from outside of a class by live chatting technique.
7) *Affordable to all Students for Subjects E-Notes and Lecture Audio Records from Top Professor* IoT in classroom makes easiest way of collecting and sharing subjects e-notes and lecture audio records to everyone in that particular network easily.

## IV. IOT IN EDUCATION IN BANGLADESH

### A. IoT in Bangladesh

Although Bangladesh is a low-income and developing country, it's among the 18 countries internationally which has shown prodigious progress in terms of human development index. As per the Human Development Report 2016 [35], among the south Asian countries, Bangladesh's position promoted one place while position of other countries with large economy could not show significant improvement. [34]

The concept that everyday objects will communicate with each other by themselves using internet of things (IoT) is yet a very difficult model for Bangladesh. However, the attention in the IoT among the tech-loving academicians, researchers, and entrepreneurs there is rising stronger. In addition, Bangladesh government has openly declared the Vision 2021 which targets establishment of a modern technology dependent country, Digital Bangladesh [36] by 2021 through effective use of information and communications technology (ICT). The four elements of Digital Bangladesh Vision are human resource development, people involvement, civil services and use of information technology in business and other areas. Bangladesh is set to be a middle-income country by 2021. To achieve that status, the country needs highly skilled workforce equipped with innovative and creative abilities. Higher education is recognised today as a capital investment and is of paramount importance for economic and social development of a country by ensuring the graduates are skilled enough.

*B. ICT in Education*

"Education is the backbone of a nation". If a nation is to be improved, everyone should focus on the education sector to ensure the quality of education. It is simply if someone want to enhance the quality of education, then they must provide an appropriate environment to the learners, academicians and teachers. In this case ICT can play a vital role to make an amiable and expedite environment.

Information and communication technology (ICT) is one of the most important driving forces promoting the economic-growth in the economy. However, there is less of a consensus among Economists on whether the impact of ICT also stems from higher total factor productivity (TFP) growth and improved efficiency of production (due to a better educated population). 2 During the last two decades, countries have invested heavily in ICT. Indeed, the use of ICT in Education and training has been a key priority in most countries in the last decade, although progress has been uneven. ICT has had a major impact on the education sector, on organization and on teaching and learning methods. Yet there are considerably different ICT expenditure levels within and between countries, as well as between institutions within countries [37].

*C. Limitations of implementation of IoT in Bangladesh*

Within a very few years, Information and Communication Technology (ICT) has turned out to be an effective educational technology which promotes some dramatic changes in teaching and learning processes. Technologies allow students to work more productively than in the past, but the teacher's role in technology-rich classrooms is more demanding than ever [38]. ICT has the potential to transform the nature of education (improving teachers' design work, enhancing the roles of students and teachers in the learning process and helping to create a collaborative learning environment, etc). Although ICT has the potential to improve the educational system to a great extent, developing countries are far from reaping these benefits because of certain barriers [39]. IoT implementation is much more difficult because of some major common barriers as follows:

*1)* Infrastructural barrier
*2)* Equipment availability barrier
*3)* Software and technological barrier
*4)* Storage and network barrier
*5)* Legal and security barrier

Despite these barriers low-income and developing countries have some special barriers for implementing latest technologies; since, everything related to new technologies are expensive. So, cost optimization is one of the biggest challenge for IoT technology designers.

Considering limited wealth and resources of developing countries like Bangladesh, implementation of IoT is not as easy as pie. But, it can be ensured that IoT will comfort the learning environment and open some ease ways of learning.

*D. Current University Campuses in Bangladesh*

Just like it is informed earlier that insufficiency of wealth and resources in developing countries like Bangladesh are the main limitation for accepting or implementing new technologies. The conventional teaching-learning environment at the universities in Bangladesh still exists, especially in the public universities. All the recently established universities and also some of the other older universities are practicing almost the same traditional teaching-learning procedure.

Campus digitization has taken place in some of the universities as an exertion of making Smart Campus. But, Smart Campus using IoT directed technology is still a dream. Considering all these, developing an IoT enabled Smart Campus with automated services is a big challenge in developing countries for the specialists.

*E. Resources available in HSTU*

With Bangladesh perspective, the relative scenario of teaching-learning in the public universities in Bangladesh is tried to be depicted considering Hajee Mohammad Danesh Science and Technology University (HSTU) as a reference. It is a university where students learn from different branch, like- life science, engineering & technology and social science. It has almost sufficient class rooms, labs and library facility for all the students. But, all the facilities are provided in traditional ways. As a result, the increasing number of students are deprived from getting the facilities though they should get these easily. The traditional way of services that the students are getting there are:

*1)* *Classroom Services:* Classrooms have the traditional Marker-White board for presenting contents and ideas. Some of the classrooms also have the audio-visual presentation facilities with projector and sound system along with other utility electric

devices like light, fan, AC etc. Some of the buildings and classrooms also have the light and motion sensing bulbs. It also has a Virtual Classroom equipped with interactive display, projector, sound system, camera and high-speed internet connection for video conferencing and sharing the lecture materials with most of the universities in Bangladesh for cooperative research work and knowledge sharing. With the digital contents of study materials is not enough. In this traditional way, students have to make class notes and the content sharing process is anguished. If someone is absent, there is no way to get the lectures.

If there be some interactive IoT enabled classrooms and lectures be recorded, shared easily to each of the students at least in the same network in the university and stored in a cloud automatically for future use; this would be a convenient way of learning.

2) *Lab Services:* Labs have also the same traditional presentation system with audio-visual presentation facilities. Lab is also equipped with computer, subject respective equipment and internet connectivity. Practical experimentations are instructed directly by the teachers and sometimes students need helps from the Lab Assistants who is assigned for a specific lab. Lab Assistants have to assist students and keep record of the equipment or materials available in labs. If there be some kind of digital manual for all experiments and IoT enable management system for keeping records would make lab more advantageous.

3) *Library services:* Library has a large collection of books and a computer room for digital library that contains a large number of eBooks and a significant number of national & international journals and research articles. Now, the students have to go to the library physically to collect the study materials. But, if the all the contents of the library including lecture notes be available in digital version and be directly sharable or synchronizable with the devices of the students would help and make the learning faster and easier. Moreover, if the conventional teaching-learning system of an institute be replaced with IoT enabled smart institute; it will make the learning environment so easy, convenient and effective for teacher, student, researcher and everyone.

## V. POTENTIAL OF IOT IN BANGLADESH

Increasing use of technologies in the Education sector is clearly visible to enhance teaching-learning experience in Bangladesh ranging from elementary schools to secondary to higher secondary to colleges and universities. Almost every classroom is equipped with a ceiling-mounted digital projector to deliver rich content materials to students along with a sound system where necessary [Need citation]. Although this scenario is common to almost all private universities and colleges, many state universities still have traditional white board and marker facility. The concept of Smart Classroom still exists in Research only. And as discussed earlier, lack of funding of universities to invest on such advanced technological structure restricts them to implement a IoT enabled Smart Classroom. With minimum cost, it is explored in below sections how to avail small scale and minimally featured IoT enabled smart classroom, laboratory, and library applicable to HSTU which is the model of majority of public universities in Bangladesh.

### A. *Smart Classroom and IoT*

A Smart Classroom should have facilities at minimum. They are - digital projector able to take input from different sources like VCR & DVD, Computer/Laptop, and a document camera. VCR/DVD plays audio/video format lecture content, and document camera projects a paper page through the digital projector [30]. In addition, a smart board should also exist along with dry erase white-board. A smart board possess quite a lot of features. Smart classroom should also have facilities to record class lectures for reference at some later time. Also, a student authentication system should also exist to eliminate traditional manual attendance system.

Purchasing necessary hardware for turning a classroom that has only a digital project and audio amplifying system to a Smart classroom may not cost much and university like HSTU should be able to afford that. The central software module to synchronize this hardware together could be quite expensive. There are quite some lot market leading smart classroom management solutions available with ranges of features. Some of the solutions are ABTutor, NetOp, and SmartClass**.**

Any proprietary solution as mentioned above has costly licensing model. To develop such solutions locally motivating students to carry out as project work could be an alternative to minimize costing and develop customized solution module by module over a period of time. Such motivation will help to improve software development skills of students as well. There are also some open source solutions available in the market which students can grab and customize as necessary. Once such a structure is functional, next focus could be on application of IoT by integrating components of a Smart classroom and enabling individual hardware module to sense events and communicate data to remote location.

For example, consider a classroom door equipped with a RFID reader could read a student's ID card data and authenticate with central database to enter the classroom. This event is stored into the central database with proper time stamp and communicates with door opening system to open the door. This activity later can be used to calculate a student's attendance. When a teacher gets through the door, any particular event initiated by him should be able to start recording the class lecture and store locally in

classroom computer or a file server in the campus Local Area Network (LAN). Efficient video compression should be used to best utilize file server space. These resources should later be available to students using a web based platform upon valid authentication either to local students or students in remote places.

If students need to be monitored closely, parent of an absent student should be able to send notification (SMS or Email) by the server application which is configured accordingly.

### *B. Smart University Building and IoT*

Occupancy of a classroom sensed by automated RFID detection is not applicable to common rooms which needs different arrangement. Common rooms like campus canteen, library reading room etc., could be equipped with heat sensors which transmits data using Bluetooth to nearby access point that in tern, sends it to server to store. A common room with student capacity of approximately 50 may require 5 to 10 such sensors. CSE faculty students could easily build such a system with minimum cost. Central web solution can parse those heat sensor data and generate heat map per such common rooms which helps students to decide if resources are available or not. This will save students time greatly and help them to plan effectively. Such sensor data could also be used to optimize the use of electricity by automatically turn on/off light, fan or air cooler based on presence or absence of persons in the classroom or common rooms. Note that motion sensor is already employed in certain HSTU buildings to automate light on/off after office hour to have efficient use of electricity as a test basis and which is very successful. Campus wide deployment of student made such motion sensor based light on/off system will greatly reduce electricity consumption. In second phase, these motion sensors could be turned into smart things to communicate data to server which is stored for any further service including administrative monitoring of buildings and resources.

### *C. Smart Laboratory and IoT*

Generally, computer labs are air conditioned and equipped with modern desktops with broadband internet connectivity. Digital projector and sound system is quite common. However, the laboratory does not have much facility to control and manage students' computers to better enhance teaching-learning environment. To make computer labs smart, there exists different monitoring and lab class management software solutions, among them some open source platforms proved quite promising. Veyon (www.veyon.io) is one of them – it is an open source computer monitoring and classroom management software supporting Windows and Linux. It enables teachers to view and control computer labs and interact with students.

Other types of laboratories like Physics and Chemistry laboratory are still very traditional. Lots of research efforts are under way to track and monitor lab objects. In addition, creation of a web-based virtual lab environment to reach students outside a laboratory is already launched. MIT researchers had been experimenting with online learning for a decade, developing an electric-circuit simulation package called WebSim that tried to give online students an effective substitute for hands-on laboratory experience.

IoT can be used in physical laboratories, like in Chemistry laboratory to monitor the stock of chemical drums if materials are running out and can communicate this event to server. At minimum, such notification data can be used to monitor and better manage laboratory chemicals and other raw material stock which in turn helps to forecast budget for next year.

### *D. Smart Library and IoT*

Library books, in most libraries, contain bar code to be tracked. QR code also quite popular due to its fast readability and greater storage capacity compared to standard UPC barcodes. IoT has a huge potential for libraries. It provides rich library experience to both users and librarians. Since IoT promotes smart objects and connection between them, some library objects can be tracked if they are misplaced from their intended location.

An IoT thing/object not necessarily be a hardware sensor always. A thing can also be a software agent which is capable to make a thing smarter. A smart phone application can have communication with library so that the application notifies student about overdue books and the amount to be paid as penalty. If such smart phone application usage is made mandatory in a university, then a lot more services can be thought of which falls in the domain of IoT. Library can easily track its inventory. A student when browsing library catalogue from the smart app, may select a book to borrow which can be marked as reserved for a threshold period of time for that student. In addition, after selecting a book, based on historical data, web application can show recommendations relating to that book.

Smart phone application which is an IoT agent, could also be used to set favourite bookmark to a book wishing to receive any update version as soon as its arrival. In that case, smart app can notify student in the smart application of new arrival [C2].

Library smart application usage history can be used to generate demand of books by linking smart classroom instructor's recommendations of books automatically. This could help libraries to prepare budget for next year book acquisition.

Library premises can be tracked and managed same way a common room or classroom is managed as described earlier in this text. Using heat map, students can visualize if a library reading room is occupied. By browsing online catalogue and availability of book copies, student can decide if he should go to library or not and this saves time and energy for students. Optimum usage of electricity can be ensured as well by using communicating sensors.

## VI. CONCLUSIONS

IoT enabled teaching-learning environment is apparently more engaging for both teachers and students as observed in different literatures and industry as well. However, till today, the concept of IoT, application framework, inter-object communication protocol are still in developing stage and require more time to maturely incorporate heterogeneous objects into single converged network and environment. Feature list that could be imagined to make teaching-learning environment better is limitless, but implementation is only dependent on the present state-of-the-art technologies. Such implementation can easily be estimated as quite high level of cost. In a low-medium income level country like Bangladesh, smart classroom is missing in most of the educational institutions, let alone the application of IoT on top of smart classroom. Authors of this paper tried to propose a theoretical incremental model of minimal increment step on how to incorporate smartness in objects which is the core theme of IoT. However, it is obvious that lots of issues would be surfaced which implementation of such a system is in progress which is the main concern of authors future work.

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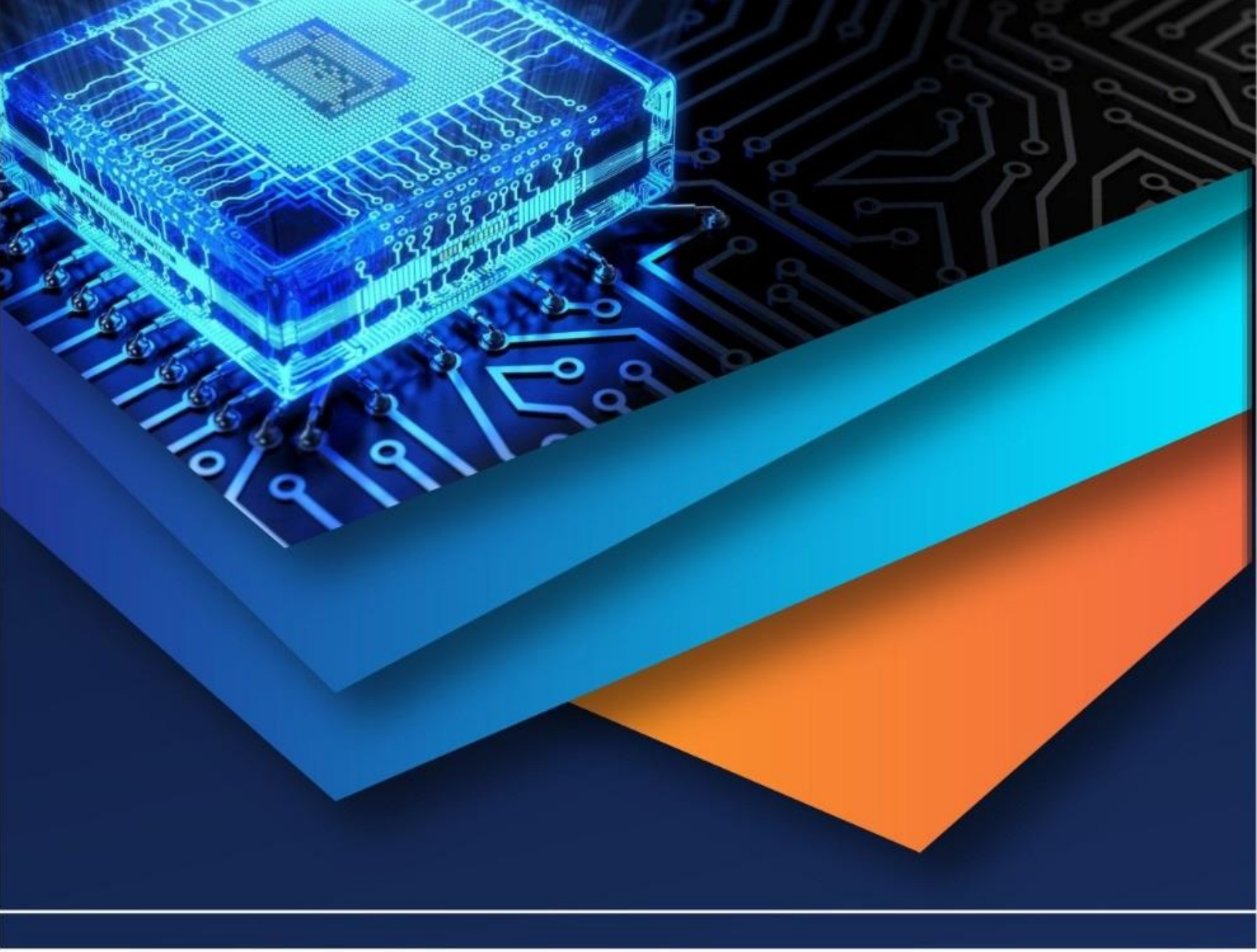

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