UNIVERSITY OF EDUCATION, WINNEBA

INTERNET OF THINGS FRAMEWORK DESIGN FOR SENIOR HIGH SCHOOLS IN GHANA

YENDAW FREDRICK

MASTER OF SCIENCE

2020

UNIVERSITY OF EDUCATION, WINNEBA

INTERNET OF THINGS FRAMEWORK DESIGN FOR SENIOR HIGH SCHOOLS IN GHANA

YENDAW FREDRICK

A Dissertation in the Department of Information Technology Education, Faculty of Technical Education, submitted to the School of Graduate Studies in partial fulfilment of the requirements for the award of the degree of Master of Science (Information Technology Education) in the University of Education, Winneba

MAY, 2020

DECLARATION

STUDENT'S DECLARATION

I, **YENDAW FREDRICK,** declare that this Dissertation with the exception of quotation and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE:……..

DATE:……..

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of Dissertation as laid down by the University of Education, Winneba.

MR. WILLIAM ASIEDU

SIGNATURE:……..

DATE:……..

DEDICATION

I humbly wish to dedicate this research work to my late father (Mr. Yendaw Banuenye) and loving mother Zaaminnu Kan-Esonma, Mr. Raymond Gyaang, friends and family for their unmeasurable support towards my education and future progress.

ACKNOWLEDGEMENT

It is difficult for me to thank all those who have assisted, guided, and contributed in diverse ways in directing the writing of this dissertation report. However, my sincere gratitude goes to my family, friends, and supervisor, Mr. Williams Aseidu for his relentless guidance, support, and encouragement throughout this dissertation report.

To my colleague teachers and course mates, I am grateful for support and encouragement.

TABLE OF CONTENTS

CONTENT **PAGE**

LIST OF TABLES

TABLE **PAGE**

LIST OF FIGURES

FIGURE **PAGE**

LIST OF ABBREVIATIONS

IoT	Internet of Things
SHS	Senior High School
IFD	Internet of Things Framework Design
RFID	Radio Frequency Identification
WSN	Wireless Sensor Networks
NFC	Near Field Communication
M2M	Machine to Machine
H2H	Human to Human
T2T	Things to Things
H2T	Human to Things
IoT-GSI	Global Standards Initiative on the Internet of Things
UNESCO	United Nations Educational Scientific and Cultural Organization
ICT	Information and Communication Technology
ITU	International Telecommunications Union
SVM	Smart Vehicle Management
ISDN	Integrated Services Digital Network
NIST	National Institute of Standards and Technology
NTIA	National Telecommunications and Information Administration
SDOs	Standards Development Organizations

ABSTRACT

Stakeholders of our educational system/sector currently face a significant challenge of school management and administration including (monitoring, supervision, and control activities) of staff, students, and material resources. That is, in recent times there is a rise in cases of kidnapping, fraudsters, illegal entry of school through the fence, rampant stealing, monitoring, and invigilation challenges that need to be addressed with an IoT application technology in our senior high schools in Ghana. This study aims to identify the key areas for the design of an IoT framework. Purposefully, this research is to assist schools to overcome the numerous challenges faced by providing intelligent collaboration and connectivity with devices. In it, the researcher reviewed related literature on IoT framework design, conceptual and theoretical review of concepts, and related theories to the study. To gather factual evidence in support of the research problem, further literature was discussed on various smart campuses and IoT frameworks and their connection or relationship with the IoT design the researcher proposed at the end of the study. The researcher adopted a methodology of an outline of steps generally use for designing IoT frameworks. Seven basic methodological steps were adopted in the design process starting from the purpose and requirement specification through to the framework functionality/operations. These steps and design tools serve as the basis for the design of my framework purposely directed for senior high schools in Ghana. Meanwhile, the researcher produced a simulation of the framework design in direct relation to areas of specification of the reviewed frameworks and models in the literature review. Furthermore, the researcher recommended that further research can be conducted on IoT security and privacy issues to ensure a well-secured IoT design. Finally, after going through all these studies, the researcher was confident to state in clear evidence that the outline of steps adopted indeed yielded to the design of the proposed IoT framework for senior high schools in Ghana.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Chapter one looks at the entire project which consists of the Background to the Study, Statement of the Problem, Purpose/Rationale of the Study, Research Objectives as well as, Significance of the Study, Definition of Terms, and Delimitation of the Research.

1.2 Background of the Study

It is an open knowledge that our Ghanaian educational system, especially senior high schools in this era of technology still operates in a traditional and non-technological environment of a manual and ineffective control system to resolve persistent challenges in our schools. For this lack of policy direction to embrace technology in the day to day administration of schools, administrators will continue to face challenges in invigilation, office management, monitoring and supervision, fraudsters, and kidnapping activities. Considering the numerous setbacks in our senior high system, the study seeks to research on how IoT technology can be employed to solve these challenges.

Internet of Things (IoT) "is not a standalone form of technology, but rather it is an integration of different technologies that interact and operate together as one" (Sethi & Sarangi, 2017). A more formal definition positioned by the International Telecommunications Union defines it as "enabling advanced services by interconnecting (physical and virtual) devices on existing and emerging information technologies" (International Telecommunications Union, 2012, para. 3).

This means that IoT technology will be applied to physical objects to give them a virtual presence. So, this emerging technology (IoT) is aimed at connecting in-built electronic devices to our day to day material objects or "things" to behave as smart controllable devices. Hence, these smart objects, which will be connected to the Internet can be uniquely identified and communicate with one another. Mitew (2014, p.5) clarifies these parameters in more detail:

> *... the IoT stands for the connection of usually trivial material objects to the internet – ranging from toothbrushes to shoes or umbrellas. This connectivity allows smart objects to transmit sensory data or information remotely, and to process material settings with available data captured. As a thing is connected, every device requires a network address that will be used as a unique identity. Every device has a bit of designed sensing capability that it uses to register changes to its operating environment and transmit the said information over the internet.* Thus, performing complex tasks for the benefit of man.

As indicated, these smart objects (devices), will require the ability to collect data, process, organize, and transmit information effectively and efficiently in any particular area of application. However, the ability of these "Things" to function effectively will only be possible through the use and integration of existing technologies such as smart sensors, NFC (Near Field Communication), Radio Frequency Identification (RFID), Bluetooth, Zigbee, Wi-Fi, Ethernet, WiMAX, GSM, as well as the Internet itself and other mobile technologies. With the integration of all these into a holistic system framework design, the IoT environment will be made up of a global variety of devices ranging from complex and powerful network servers to simple RFID tags. Hence, given the framework design of the internet of things a heterogeneous background, though

some electronic devices will be constrained in performance (i.e. some of the devices may be limited in processing capabilities, power, and memory).

Education can be defined as a way of making people better informed and wiser through acquiring knowledge and skills. As such, people create awareness of responsibility and capability to significantly contribute to the world progress. In other words, the education outcome – research, invention, innovation, and adaptation enhances the processes of recognizing and dealing with the challenges while resolving the problems of nature. Hence, education is the most effective mean of making the world a better, safer, and more sustainable place to live, which makes it the best investment (UNESCO, 1997).

The role of education in all spheres of life and society progress implies the demand for the continuous betterment of the education sector. The tremendous growth in the technological field has a great deal of effect on education, thus transforming the teaching and learning approach on a global scale. The application of emerging technologies in education has helped to create a more effective, student-focused, and issue-focused activities at our various schools (Gupta and Fisher, 2012).

In recent years novel, Information and Communication Technology (ICT) solutions completely change the traditional educational process leading to the significantly improved modern and quality education systems at various levels of learning especially senior high schools. There are currently seven categories of technologies, tools, and strategies that revolutionize the educational sector: consumer technologies, digital

strategies, enabling technologies, Internet technologies, learning technologies, social media technologies, and visualization technologies (Johnson et al., 2015).

As a part of Internet technology, the Internet of Things (IoT) has enabled that every device/"thing" becomes connected to the internet opening a whole world of potential improvement on a global life scale. In other words, the IoT inclusion in the senior high educational environment successfully overcome the gap between the traditional education system and our smart campuses by modifying the traditional classroom settings challenged by location and time into smart and interactive classrooms of unified and available internet and communication devices.

In the school environment, internet of things (IoT) is considered as a global infrastructure for the information society that can facilitate the interconnecting of all types of objects such as physical and virtual things based on telecommunication protocols and technologies that expands interactive communication among human to human (H2H), human to things (H2T) or things to things (T2T) as presented in figure 1 below.

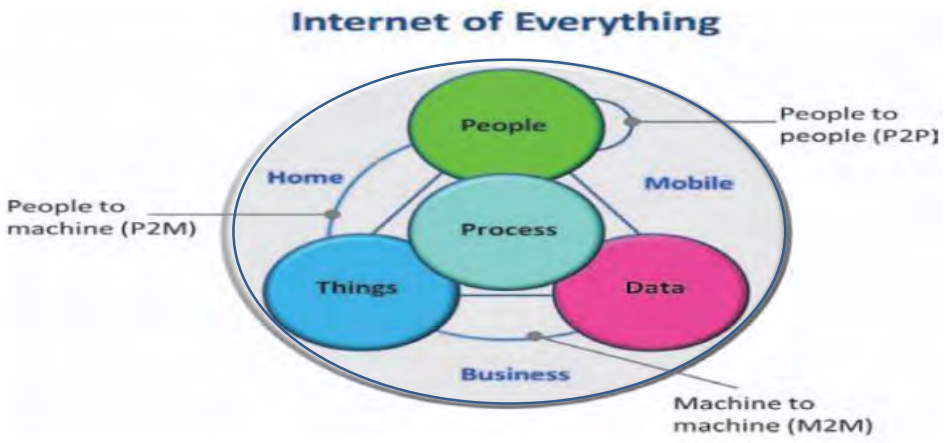

Figure 1: Internet of everything

Source: Cisco, 2012

Internet of everything is a complete connection of people, objects, and machines that collect and process data and information in business organizations and home to form a network of people and things around us as shown in figure 1 above. Therefore serving as the basis for the design of different IoT frameworks for organizations especially the education sector.

Hence, the senior high educational practice has been dramatically influenced by IoT advances. This technology progress has significantly improved the delivery method of courses as well as content, improve administrative monitoring and security awareness by adding more resources and tools to the classroom, school fence physically or online, and making the learning more dynamic and interactive (Advanced MP Technology, n.d.; Vujović and Maksimović, 2015). Therefore, IoT brings completely new levels of connectivity and advanced learning approaches in educational practices. However, it also brings certain challenges and concerns, mostly privacy and security issues regarding students' "personal and grade information" (Advanced MP Technology, n.d.).

The important aspect of the IoT utilization in educational institutions (i.e. Senior High Schools in Ghana) is its potential, not just to raise the quality of education, but also to realize an economically, socially and environmentally sustainable education sector (Maksimović, 2017a). Thus, this vision opens a new horizon of ideas and development resulting in the need to design an IoT framework for schools as already being proposed by research scholars and academics.

1.3 Statement of the Problem

The research problem of this study arises as a result of the numerous challenges senior high schools face in the day to day administration within the school environment. Firstly, in recent times school base fraudsters and kidnapping for financial and social benefits by bad nuts in our society is at a high ascendancy in our various educational institutions of Ghana. In the early days of the year (2019) three school-going age girls were kidnapped and after almost two years they have since not been found. In recent times, criminals are adopting new forms of ways such as false fabrications (reporting to parents about emergency situations of their ward in school) to extort parents for their financial gains.

Secondly, monitoring, supervision, and control activities in schools are matters of serious concern to school administrators and government in our senior high educational system of Ghana. This challenge has caused the government and administrators thousands of financial and material resources.

Thirdly, invigilation challenges, scaling of the school fence, and illegal route of entry by both students and or strangers are rampant occurrences at the senior high school level.

Furthermore, it is also obviously clear that many of our educational institutions (SHS) run away from bearing the cost element of technology as well as the conceived level of misconception stakeholders perceived about the applications and adoptions of technology in our senior high institutions regardless of its benefits. Thus, considering all these numerous challenges and technological shortfalls in our senior high system the researcher decided to dig deep into research in an area that can resolve the situation and also stand the test of growing technology in society.

Thus, the recent cases of kidnapping, fraudsters, illegal entry of school through the fence, rampant stealing, and monitoring and invigilation challenges motivated the researcher to study into an IoT framework for senior high schools in Ghana.

1.4 Rationale/Purpose of the Study

IoT is a global physical network that connects devices, objects, and things to the Internet infrastructure to communicate or interact with other devices within us, all for the reason of information exchange via sensing devices according to system design protocols.

Thus, the purpose of this research is to assist schools to overcome the challenge of monitoring, supervision and control activities in schools by providing intelligent collaboration and connectivity with devices anywhere and at any time for students, teachers, school administrators, and other officers to be connected around the globe through internet/networked services (Friess, 2013).

Furthermore, the purpose of this study is to help prevent the recent incidence of school base fraudsters and kidnapping through the intelligent tracking system, sensory identification as well as control management (Stankovic, J.A. 2014), to assure parents of student safety and comfort.

Again, another purpose of this research study is to help solve invigilation challenges within the school setting, illegal entry of school environment by students or outsiders, and at the same time prevent stealing and property destruction on campus.

The adoption of this IoT framework design for SHS in Ghana will help us to improve upon the general school base operational management in Ghana.

1.5 Specific Research Objectives

1. To identify the key areas for the design of an IoT framework for SHS in Ghana.
2. To design an IoT framework for Senior High Schools in Ghana.
3. To identify the benefits of IoT framework in Senior High Schools.

1.6 Significance of the Study

In identifying the significance of designing an IoT framework for SHS in Ghana, a number of research organizations and analysts predicted about IoT and the future. Juniper (2015), estimated that about 13.4 billion IoT devices will be connected by 2015, representing a figure far more than the earth's total population at the time, meanwhile, the number is expected to triple to a range of 38.5 billion devices by end of 2020.

Hence, the opportunity of interacting with IoTs of everyday objects connected to the internet allows for students, teachers, parents, administrators, and individuals to be granted access to available information at convenience. The IoT framework will provide a biometric check system of attendance for both staff and students as well as change how teachers deliver lessons and test achievement through smart and digital devices.

Also, the study will help simplify operations for school administrators by proactively monitoring staff and critical infrastructure while creating a more efficient, cost-effective processes in human and material management. Thus, assuring parents, students, and teachers of a safer and secure environment through the adoption of digital surveillance cameras, smart doors, IoT fence, and tracking devices that will help in the control of this menace in senior high schools of Ghana.

Moreover, the study will enable institutions (SHS) to create new ways for students to learn by supporting more personalized and dynamic learning experiences such as game-based learning, e-books, smart boards, e-assessment, and tracking and monitoring systems.

Finally, the Internet of Things (IoT) has the potential to transform education by profoundly altering how senior high schools in Ghana gather data, interface with users, and automate processes.

1.7 Delimitations of the Study

The research is conducted to cover Senior High Schools in Ghana. The study will be adoptable by all SHS in the sixteen regions across the country inclusive both government and private institutions. The study is also conducted to be limited to the Internet of Things (IoT) framework design for senior high schools in Ghana due to certain uncontrollable constraints such as funds and time.

1.8 Definition of Terms

Term	Description
Internet of Things	The IoT is a global physical network that connects devices, objects, and things to the internet infrastructure to communicate or interact with other devices within us for information exchange via sensing devices according to system design protocols.
Framework	In computer systems, a framework is often a layered structure indicating what kind of programs can or should be built and how they would interrelate.

Design	Realization of a concept or idea into a configuration, drawing, model, pattern, plan, or specification (on which the actual production of an item is based) and which helps achieve the item's designated objectives.
Smart Campus	Smart campuses are defined as places where devices and applications create new experiences or services and facilitate operational efficiency.
Education	Education can be defined as a way of making people better informed and wiser based on a level of knowledge and skills acquisition.
Information	Data that has been processed in such a way as to be meaningful to the person who receives it. it is anything that is communicated.
Smart Devices (ie Objects or 'Things')	An electronic device generally connected to other devices or networks via different protocols such as Bluetooth-NFC-WiFi-3G-etc. that can operate to some extent interactively and autonomously.
IoT Service	Any computer program that leverages data from IoT devices to perform tasks.
IoT Service Provider	Enterprises or organizations who develop new and innovative connected products and services for IoT
Updates	An update may include additional functionality to the software package as well as patches for specific issues.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The main purpose of this study is to design an IoT framework for senior high schools across the educational institutions within the country. This chapter throws light on what earlier researchers and authors have written and said about the topic. This review will consider IoT framework design, IoT domain/ application areas, and benefits of the Internet of Things in education, conceptual review, and theoretical review.

2.2 IoT Framework Design

IoT framework design is domain-specific and should be designed based on the adaptabilities of applications. The internet of things (IoT) can be considered as the general connectivity of devices existing within the information and communication environment in which technology operates. This emerging form of technology has improved computer services through the interconnecting of (physical and virtual) objects depending on already existing technologies (ITU-T Global Standards, 2012). The goal of this framework design is to enable the connection of objects around us at any time, anywhere and with anything using any network or service.

2.2.1. IoT architecture

The IoT architecture is usually considered as a network of devices, objects, and computers of all types and sizes (Amr & Mohamed, 2017). Internet of Everything (IoE) connects people, data, things, and processes in networks of connections to serve a common purpose (Evans, 2011).

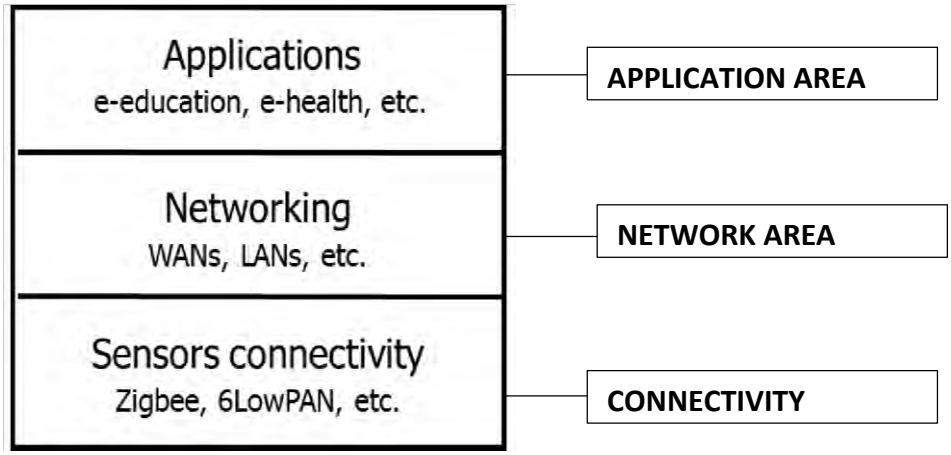

Figure 2: Overall IoT Architecture (Amr & Mohamed, 2017)

IoT communication is based on interoperable protocols operating in heterogeneous environments and platforms (Vermesan, & Friess, 2013). These IoT interconnections of different devices are made possible by the use of protocols on the sensor layer (including Bluetooth, Zigbee, etc) and different network connectivity (including LANs, MANs, and WANs) in the network area of the architecture. The application area describes the system applications that this IoT architectural technology can be used to operate. So, in order to implement any IoT architecture, framework, or model in any organization there is the need for sensory devices, network connectivity, and the application platform as in figure 2 above for the system to function to its full expectations.

To enable smart educational applications in our senior high schools, the IoT infrastructure (framework) must be put in place. This is to allow smart objects to participate in the educational process. Figure 2 shows the overall IoT architecture and illustrates the relationship between the applications and the infrastructural framework. IoT frameworks allow for the connection of billions of devices and sensors that are used in creating the application. The motivation is its ability to be used on-demand and as per the requirements of the specific application (Buyya & Dastjerdi, 2016). This overall

architecture is serving as the basis on which the researcher's IoT framework design will be developed taking into consideration key elements like sensory device connectivity, networking, and software applications.

2.2.2. IoT reference model

Currently, research shows that there are no accepted standards of the internet of things models. Thus, Cisco's creation in figure 3 below is one, if not the most appropriate; it has been chosen to depict the internet of things levels in a visible appealing way.

Cisco's internet of things reference model as in figure 3 below is based on information flow in bidirectional and could be seen as a cornerstone for the understanding of internet of things relation levels;

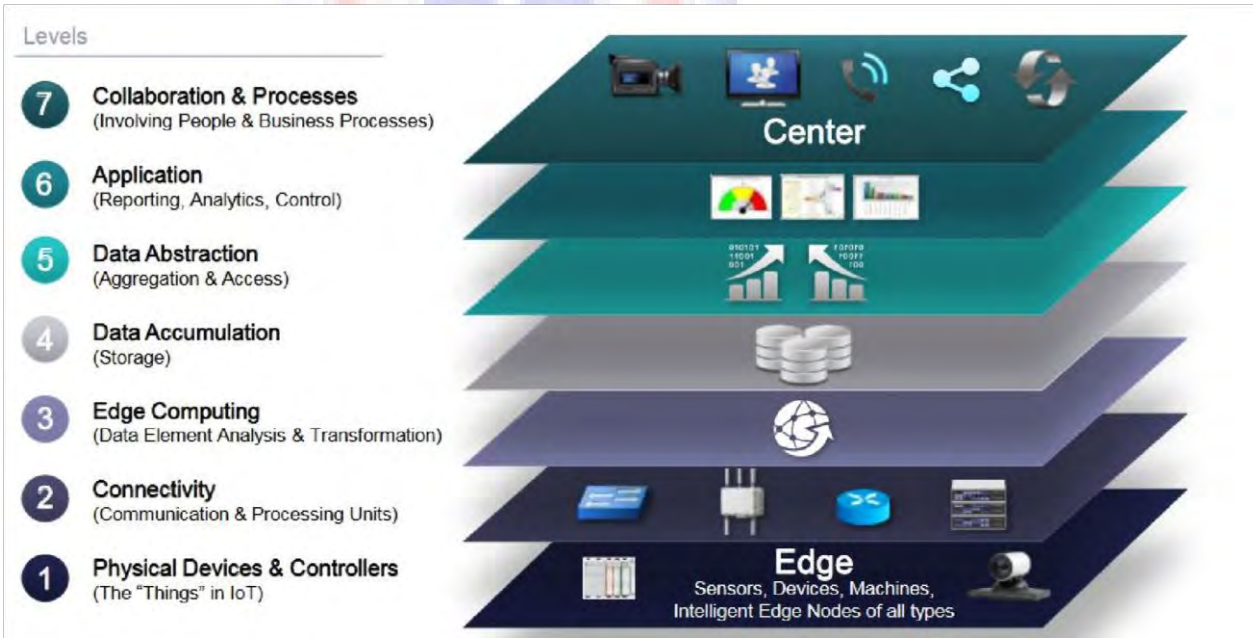

Figure 3: IoT reference model: Source; Cisco systems 2014

Stage 1: devices in this stage are well equipped with some sensors and are neither location bound nor size restricted. Thus, they mostly generate data and as such can be controlled.

Stage 2: In this stage, communication between devices and levels are enabled by network connections. Thus, it is done by encoding, routing, and switching of the communication and processing units.

Stage 3: data is converted into information that can safely be kept by filtering analysis. These may include formatting, evaluation, and reduction.

Stage 4: At this stage, data is now safely kept and remains dormant, and ready for further usage and processing where necessary.

Stage 5: In this stage, the data is sent and consolidated into other useful formats for decision making.

Stage 6: the information in this stage is interpreted by the applications based on a particular transaction/process that has been carried out since the report forms vary from one unit of application to another in the analysis.

Stage 7: processes and people in this stage are triggered for actions to be taken and executed based on the needs of the information delivered.

Considering the above model in figure 3, one will argue in favor of Cisco reference model since it will be easier to understand the extent and steps within an IoT ecosystem and hence, this step might be necessary to serve as the foundation for building future IoT models, frameworks or infrastructure for all kinds of organizations.

The systematic structure and level flow of data, network, and information of the reference model in figure 3 is a proper definition of an organizational structure to be considered in designing the framework. Organizational environments like senior high schools operate on a department basis, office units, and class levels. So, in designing the framework there is the need for proper connectivity to ensure data and information flow among the various units and departments.

2.2.3. IoT application framework

The world of education has changed through the advancement of technology. From non-existing to the usage of simple, manual and analog devices in the teaching and learning environment through to innovative teaching and learning process, and interactive education. On the contrary, these advancements are negligible as compared to the mass revolution occurring in the educational system as a result of the application of the internet of things ecosystem.

The IoT, which links people, processes, devices, and data-augments the quantity and value of the information we can collect, allowing the stakeholders of the educational sector to turn data into valuable information as never happened before.

Through the initiation of the internet of things technologies, educational organizations are able to keep track of all institutional resources. It is an undeniable fact that the Internet of things plays a major role in teaching, learning, and assessment. Moreover, the application of the internet of things will assist in the holistic delivery of resources in an innovative manner to learners. Figure 4 below is the internet of things application framework of connected objects and devices.

Figure 4: IoT Application framework: source, (https://x-systems.com/mobile-iot-security-solution/education)

This application framework in figure 4 is the interconnectivity of various objects and devices including connected buildings, connected vehicles, and other electronic and communication devices that interact and exchange information. The framework design will equally be an interconnection of the various key application areas within the school setting which are interacting and exchanging data and information to enhance school base operational and administrative performance.

2.2.4. The model of smart campus (IoT)

A smart campus is a new form of campus information that supports the overall improvement of senior high educational development. The model as shown in figure 5 includes portal architecture, management and service, smart management, smart learning, communication, infrastructure, decision support, network, and hardware resources, etc.

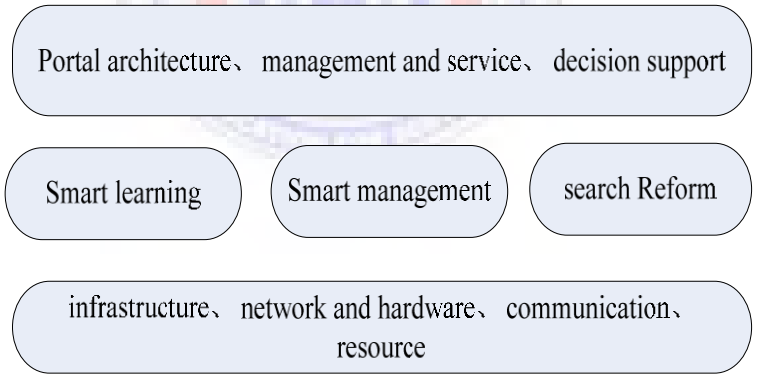

Figure 5: Smart campus model: Source, (Xiao 2013)

We should vigorously develop smart campus with IOT infrastructure, because it is a new form of fast-emerging technology that can help satisfy the demand of education, and can supply the best service for mobile management, mobile teaching, and learning, monitoring, and supervision. We can construct an IoT network of a safe, stable, and

efficient campus system if smart campuses are made an integral part of our educational policies.

Considering the model of smart campus in figure 5 above, one cannot easily identify the network of connectivity of data and information flow among the various units of the system. However, it is a model that can provide foundational data/information for building other IoT frameworks or models for organizations more especially senior high schools in Ghana.

2.2.5. Smart campus application framework

Smart school is a combination of IoT technology and cloud computing platform. We can integrate isolated systems such as educational management system, finance management system, office system, library system, student and staff information system including parents by IoT technology of systems and objects connectivity in one IoT application framework as shown in figure 6 below.

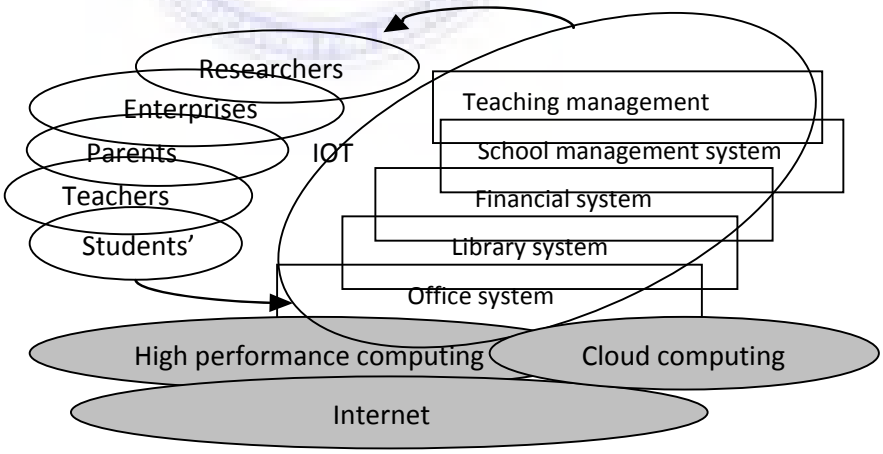

Figure 6: Smart campus application framework: Source, (Xiao, 2013).

The application framework of smart campus in figure 6 above is a combination of IoT and cloud computing based on high computing performance and internet. With the integration of the various educational units (such as teaching and learning unit, finance unit, office systems, library system etc) as a general or unified system, smart campus can make teachers, students, parents, enterprises and researchers able to communicate, access resources and interact effectively.

Constructing smart campus based on the IoT technology is an inevitable trend. However, there are questions about the top-level design. The designer ignores to dig deeply into the value of information resources, therefore making the sharing of resources difficult. Moreover, the solution of education cloud is not perfect at the top-level design, since schools attach more importance to office and teaching management than research.

Smart campus is the higher stage, so we should pay more attention to its framework design at this level in order to get a complete, unified, control and effective system that will create a set of quality standard for data manipulation, school management, safety and security through sensory objects for easy management. Indeed, there is the need for stakeholders to be concern about the development of this smart technology in our educational units. Smart campus can satisfy the demand of educational users and can supply the best service for mobile office and mobile teaching and learning. This IoT framework can serve like a network that manages all the operational and administrative activities as in teaching, learning, research, finance, library and office system as shown in figure 6 of the application model above. In the near future, smart campus needs the big breakthrough on information collection, chip research and programmed algorithm in order to ensure a complete and well-secured system.

2.3 IoT Implemented Areas

Internet of things technology has some effects on education sector either directly or indirectly (O'brien, 2016) by carrying out educational task with ease and timely, causing an overall upgrade in the teaching and learning process, quality and standard of education. The general educational operations need real and lasting solutions to its challenges and internet of things is suitable for the actual implementation in these key operational sectors within high schools in Ghana.

Once the major areas such as teaching, learning, transport, management, and monitoring and supervision are considered, the key areas will be upgraded. This, therefore, provides stakeholders with real-time information about students, staff, and resources. As such, helps in automated execution, quality decision making as well as the provision of security.

2.3.1 Smart classroom

The figure below is a representation of an IoT classroom that best describes the nature of an ideal situation of a classroom in an IoT school environment.

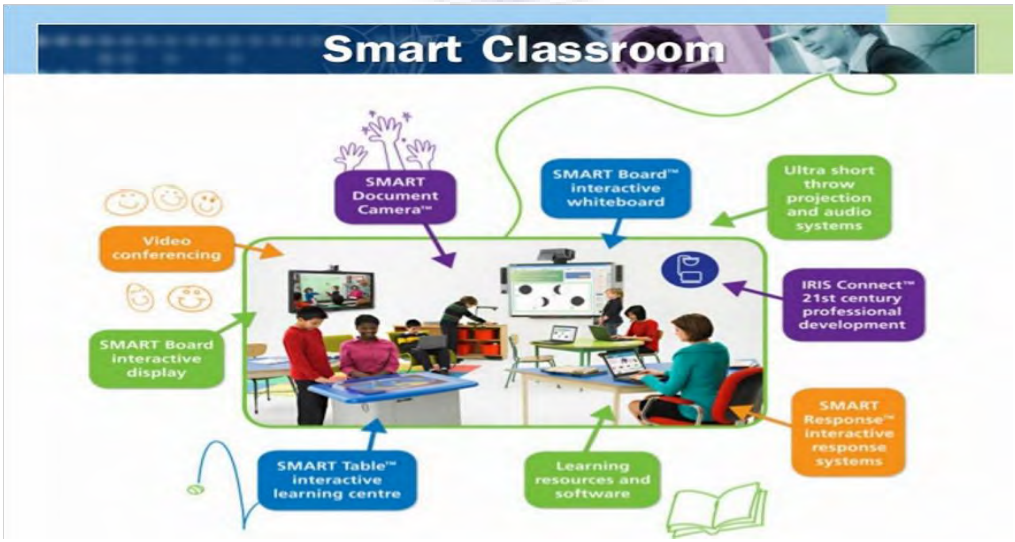

Figure 7: Smart Classroom (https://www.pinterest.com/pin/420453315183452859/)

This is an IoT technology classroom that promotes and enhances teaching and learning. The above figure 7 smart classroom is a complete connection of people and devices gaining and accessing knowledge and resources through real-time and video conferencing technology. In a smart classroom, the teaching and learning are dynamic, personalized and interactive.

Smart classroom is an emerging model that integrates technology in order to shift from the many challenges of the normal classroom. The essence of IoT integrated classroom is to move away from the traditional classroom infrastructure of manual teaching and learning activities to an effective and efficient smart teaching and learning environment. A smart classroom as indicated in figure 7 above consists of e-gadgets such as smart/ interactive whiteboard, smart door, safety cameras, projector, tablets and mobile devices, tracking attendance and network-related devices.

All these devices are available to students, teachers and administrators for the purposes of checking attendance, monitoring and supervision, measuring work efficiency and security alertness. Moreover, smart classrooms help students to understand the real purpose of using technology which also makes the learning process easier (Chang, 2011). While the records of a student's attendance are also kept at the academic office (Chang, 2011). Meanwhile, in the design of this IoT framework for high schools in Ghana, smart classroom serves as a single fraction of the whole design process as shown in figure 8 below.

Figure 8: The smart and interactive classroom (Maksimović, 2017b)

IoT adoption in education will go a long way to help students to become active participants in the classroom teaching and learning process or laboratory assessment from anywhere and at any time. They can log on, and choose the adequate manners to generate, obtain, manipulate, or display information. Hence, the novel devices implemented in the classroom, such as interactive boards, smart tables, smart learning software, cameras and digital highlighters as in figure 8 above. These smart devices will help to drastically simplify the learning experience and enhance the collaboration among students, teachers, mentors and colleagues across the world (Maksimović, 2017b). The smart classroom setup in figure 8 is an exact picture of what an IoT framework brings to the classroom of high schools in Ghana. The mood is always lively, real, resource base and very interactive to both learners and instructors in the classroom.

2.3.1.1. Smart Door

In an IoT environment, a smart door serves as a checkpoint for monitoring student and teacher attendance in the classroom. This will help to instill strict attendance and punctuality among teachers and students.

2.3.1.2. Safety Camera

Smart classrooms with surveillance cameras will serve as a source of security safety for monitoring examinations, classroom teaching and learning and other school-based activities can safely be tracked and monitored.

2.3.1.3 Smart teaching and learning

Smart base educational instruction is a special form of teaching approach that entirely differ from the manual chalk and talk system. In smart teaching, the teacher/facilitator imparts knowledge to learners through different means via the help of e-gadgets like interactive boards, audio-visual devices, projectors, computers etc. Students can check in class using card and mobile telephone that has the RFID label, the information data of the students are written to the database, where teachers and parents can monitor and track the activities of students.

Smart learning has no clear and unified definition so far. However, smart learning is the act of learning to gain knowledge with the help of electronic gadgets. Thus, the use of interactive/smartboard technology in classrooms is a step to promote dynamic and flexible teaching and learning processes, encourage individual and self-paced learning and above all create a vast pool of knowledge available for access by both teachers and students.

IoT, in general, is already viewed as an assistive technology of benefit for all – for students with a disability, this benefit is enhanced as it offers an 'accommodation rich' learning environment (Kiryakova et al., 2017, p. 80): *the internet of things may have an effect on school-based teaching and learning process, including the techniques of knowledge creation and its transmission. The learning process may be directed entirely to the participants' needs by physically connected devices. The internet of things promotes positive learning outcomes of issues that are normally considered controversial through access to more technical resources (devices) and their accompanying necessary technology applications to help transform learning in more human-oriented process.*

2.3.2. School dormitory

An IoT infrastructure within school dormitories will greatly take away the burden from teachers of constantly monitoring the activities of students including bullying, property destruction, fighting, and stealing. Creating the awareness of students about the presence of surveillance cameras, automatic timeout bell or siren will largely help to prevent negative social vices among students.

2.3.3. Administration block

School management needs to monitor and make concerned decisions about the development of the schools. Hence, the need to connect the main control unit of all the IoT infrastructural centers in the school to their access. This technology will provide school administrators the chance to supervise and coordinate school activities at their comfort.

2.3.4. Logistics/Stores

We can have intelligent management in logistics, such as school consumer, intelligent light, intelligent parking and safe control stock management. Smart campus system can help in the control and management of all these systems. Especially, the intelligent light uses auto lighting system to save energy and cost, and the intelligent parking assists to help guide the car into parking spaces.

2.3.5. Library unit

We can have a new management mode in the library by IoT. Library takes the information feed into an electronic tag. These tags combine the mobile phone, library card and other physical objects. User can get the resources required at anywhere through GPS technology. The new mode can realize the communication between user and library, user and resource.

2.3.6. Smart Bus/Vehicle

According to Kortuem et al., **(**2013**)**, internet of things technology institutional transports can easily be tracked and managed effectively with the use and help of smart and sensitive devices. Below are the various aspects of the school bus management system in figure 9.

Bus Attendance: Every student's entry attendance is normally updated on a customized cloud application with data from the RFID reader or iris scanner.

Short Messaging System (SMS): automated SIM alert for the picking up and arrival of students will be sent to parents via their mobile phones in the case of day schooling system.

Route Adherence: school management will normally get alert whenever the bus goes off the road.

Live Tracking: management will be to view the bus live while it travels on the map; thus giving more insight to safety.

Emergency management: in case of emergency, the system will be able to select the bus route, and students' details such as blood group, and parents' contacts, and immediately mail them to the hospital.

Driver Analysis: management will automatically get reports about the bus driver behavior such as timeliness, driving speed as well as the driver habits.

Preventive/maintenance: sensors and applications in the system will prevent the bus from mechanical failures by sending SMS alert when an inspection is due or if a problem is likely to arise.

Downloadable Reports and Dashboards: all reports such as staff and students' attendance, bus location, driving speed and other trends can be downloaded and accessed at any time for administrative purposes.

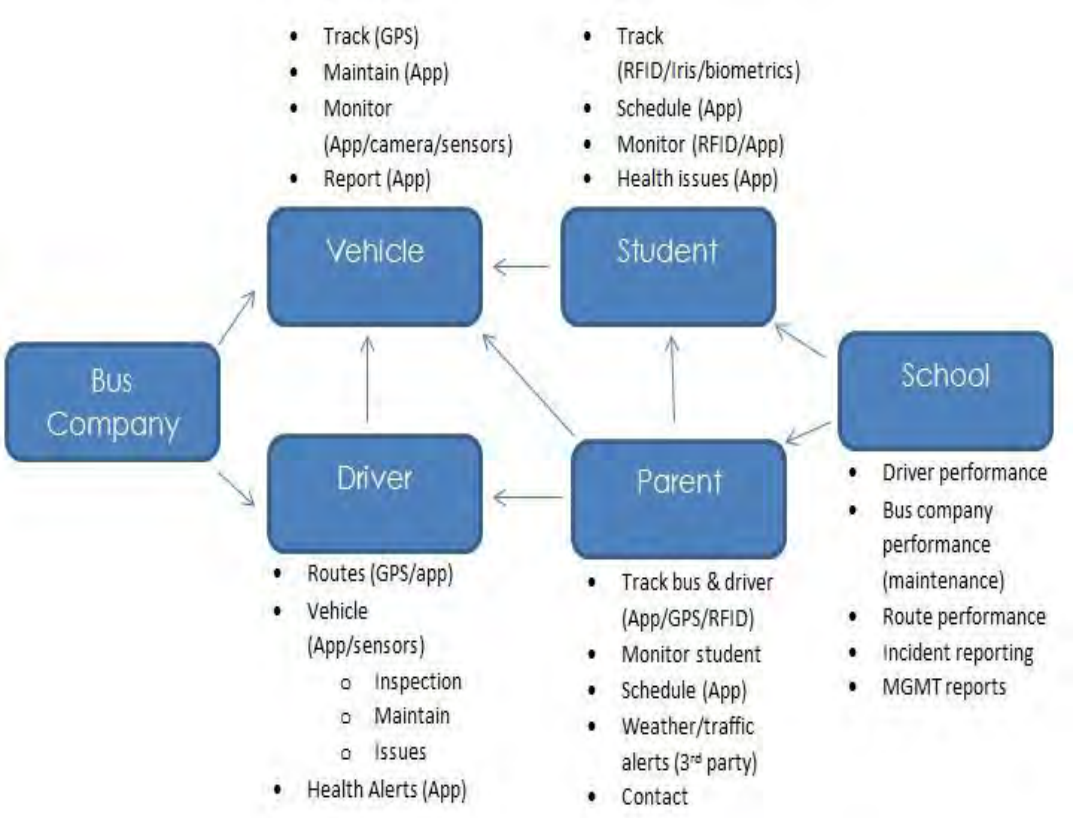

Figure 9: IoT Framework for Smart Vehicle Management (Kortuem et al., 2013)

The framework design in figure 9 above ensures effective communication among the various stakeholders including the Bus Company, driver, parents, school administrators, and students. This ability results in continuous monitoring of the bus and students at both the school and home level. School vehicle management is very critical in its implementation and integration in an IoT environment since it involves lives saving decisions. Hence, during integration, all critical steps need to be considered to ensure system connection and responsiveness.

2.3.7 IoT fence

In the school set out, installing IoT devices around the fence of the campus allows for easy monitoring of students and visitors in and out of the campus by both school authorities and parents.

2.3.8. Parent

Parents are key stakeholders in the management of schools. In that regard, they are always much concerned about what happens in those very schools due to the sacrifice and investment made. Where parents at their comfort can monitor the activities of their wards at school, they become more convinced, confident, safer, and comfortable about the assurance of total safety of their wards at schools.

2.4 Conceptual Review

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 learning of new architectural models. The mind behind this great change is the ability to design and embed sensitive sensors into objects and use computer-to-computer (C2C) communications to connect billions of objects/devices to the current Internet infrastructure. The entirety of the physical world is coming online rapidly.

2.4.1. Smart education

Sensitive and emerging technologies, such as Internet of things (IoT) will enhance material use in education that will emphasize the creation and use of smart environments for the purposes of teaching and learning including school base administration.

The main idea of smart and innovative education is to promote the quality of the everyday learning process. This emphasized on how to promote the learners' intelligence, evolving and creating problem-solving skills, critical thinking, construction and gaming ability in our smart environment. Smart education is more about digitization, technology adoption, use of electronic gadgets and smart devices in

the knowledge acquisition process either in or outside the school environment. This form of education is, becoming increasingly cheaper and can always be easily accessed at our comfort anywhere, anytime.

2.4.2. IoT and education

IoT technology has an influential role in our educational sector through connectivity, thereby resulting in a tremendous change of both the teaching and learning practices and the infrastructural stature of educational institutions (Mohanapriya, 2016).

This emerging technology (IoT) in education is a two-face technological tool since it has been considered as a foundational course and at the same can cause a transformation in the structural look of schools (Elyamany & Alkhairi, 2015). This new technology (IoT) is playing a likely role in the improvement of education at all levels including senior high schools, college, and university teaching. This improvement can range from student to teacher, classroom, campus, properties, and all that is required within the school environment.

Moreover, IoT is being used as a teaching and research medium in education. According to Marquez et al., (2016) "*IoT integration as an emerging technology in our educational environments can enhance the interactive communication between people (student and teachers) and (physical and virtual) objects within the teaching and learning environment*". Hence, IoT solutions promise to make schools and universities smarter as well as more successful at what they do. Generally, IoT has the potential to redefine how students, teachers, and administrators interact and connect to technology and devices in the classroom environment, enhance learning experiences, improve educational outcomes and as well reduce costs of institutional operations.

Below are IoT solutions for adoption in education:

- The use of Smart student ID cards, smart bus tracking systems, attendance-tracking devices, and other sensing devices to track the activities of students on campus.
- Smart whiteboards and other interactive digital media that can gather and analyze data for teachers and students for use in the classroom or anywhere else, at any time optimizing instruction and improving learning outcomes.
- Also, solutions such as smart temperature sensors, ventilation, and air condition gadgets, including smart heating devices can be used in order to reduce the cost of energy consumption and easy automation of operations.
- Wireless door locks, connected surveillance cameras, and facial recognition systems that provide security for teachers, students, and staff.
- Research programs enhanced with more advanced and automated systems in major areas of study, such as medicine, agriculture, and engineering.

2.4.3 Design technology

In designing an IoT technological framework for high schools, identifiable key elements, location, and operational ability are paramount to architects, design experts, and software developers of the IoT technology. According to Gubbi and Buyya (2013), IoT infrastructure is based on some five key elements:

First and foremost, radio frequency identification tags are used to give objects identities, locations, and make connections possible.

Also, the wireless sensor network (WSN) will enable the consolidation of sensor gathered-data, and further processing and analysis.

In the third frame, devices need to be assessed using various addressing schemes. Hence, in distinguishing between devices the IPV6 protocol is widely considered to be effective.

The next pivotal elements are storage and analytics. Thus, both elements are of general significance/importance as discussed and highlighted before. The last element is results visualization that can be presented on electronic devices such as smart/mobile phones or tablets use for connecting the decision-maker to the internet of things ecosystem. (Gubbi & Buyya 2013). Internet of things framework for senior high schools is a combination of several interrelated components, devices, infrastructure, and networkability that function with the integration of some existing technologies such as; smart sensors, NFC, RFID, Bluetooth, Zigbee, Wi-Fi, Ethernet, as well as the internet itself and other mobile technologies.

2.5 Theoretical Review

2.5.1 Design rationale theory

Design Rationale is a theory based on the ecological approach (Gibson, 1986). Carroll (2003) argued out his way as to why design rationale should be considered as a theory through a framework; he emphasized the value of capturing the theory during the design process in order to comprehend and reflect upon the system design. Design decisions are the effect of design rationale reasoning. Design rationale is a significant tool for arriving at design decisions in itself. Every framework design has an intended rationale advantage that needs to be achieved through rational reasoning. Hence, documenting the design rationale is important for understanding the context behind design decisions and validating them. This helps in the interpretation of ambiguous design decisions

and/or examples that do not fall completely within the design principle, and at the same time avoid going back to challenge or change design decisions without knowing the reasons that led to them in the first place.

So, in dealing with IoT framework architecture design rationale can be applied not only to the design of systems and structural frameworks but can also be used as a guiding architect for senior high schools and end-users to act as designers of their own suitable applications, because they can serve as a central location for framework designs and architectural work.

2.5.2 Activity theory

Activity theory is a theory of philosophical framework that has influenced organizational and educational designs including human and computer communication. Prominent researchers including Norman, Carroll, and others collaboratively used the theory in various systems research and interactional designs. This theory is a set of foundational principles that constitute a general conceptual system that can be used as a ground for more objective and specific theories to stand. Activity Theories are basically object-oriented, tool mediation, continuous development, including internal and external activities in a hierarchical structure (Kaptelinin & Nardi (1997).

According to this theory, consciousness is shaped by practice, as students mediate their activity by artifacts and objects within the reality of the school environment. Object-orientedness is a principle that indicates the role of things around us when through the magic of IoT. Hence, tool (objects/things) mediation is a fundamental concept in Activity Theory. As Bannon (1997) explained, objects/tools shape the way human beings interact with reality. This is indicated by the internalization/externalization

principle. "*Tools or objects normally is a reflection of the experiences of other persons who have tried solving similar situations before and have created or adapted the tool to make it meaningful in its application in line with the knowledge of how the tool is used"* (Bannon, 1997).

Importantly, social knowledge is gathered and transmitted via the use of things/tools, which, in turn, are influencing the very nature and cognitive processes of people. Taking the school setting into consideration, activity theory is influential in guiding human-computer interaction (Kaptelinin & Nardi, 1997). Especially computer-mediated activities and it supported general activities within our school setting. Activity theory can be used as a conceptual framework addressing how student thinking could advance further via the use of IoT technological tools in our senior high schools.

2.5.3 Constructionism theory

Constructionism is an educational theory that believed in the idea of objects construction and that students can better learn effectively through construction and interaction with things within us (Papert, 1986). The Constructionist will debate that learning becomes more and very attractive and effective if the learners are active participants in making tangible objects/things within the real world of technology.

In this framework theory, the constructionism idea corresponds to the users of the IoT framework design within the various senior schools. Students, teachers, parents, and administrators will appreciate that adopting an IoT environment will far exceed knowledge reconstruction as in constructivism to include smart security, efficiency, and IoT application development which will subsequently create a better understanding of the IoT environment and its mechanisms among various users.

Knowledge reconstruction involves many components within the learning environment. The learner in particular needs a lot of basic skills in data and objects manipulations, critical and problem-solving skills, and concrete and concept definition ability. Since the framework design will be more of object interactivity and manipulation, students/learners within the senior high setting will improve greatly in knowledge construction and understanding.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter gives a detailed description of the research procedure or methodology used for the study. It covers the design methodology and outline of steps that were used in the framework design, the structural view of the methodological steps, and the actual proposed IoT framework design for senior high schools in Ghana.

3.2 Design Methodology

According to Kothari (2004), research methodology is a theory of how an inquiry should proceed. It involves an analysis of the assumptions, principles, and procedures in a particular approach to inquiry. It is a way to systematically solve the research problem (Kothari, 2004). It may be understood as a science of studying how research is done scientifically. In it, we study the various steps that are generally adopted by a researcher in studying his research problem along with the logic behind them.

It is necessary for the researcher to know not only the design methodology but also the operational abilities of the framework since researchers need to understand the design assumptions underlying the various steps and requirements that need to be known and as well be applicable to this IoT framework design. All this means that it is necessary for the researcher to design a logical methodology for achieving results as indicated in figure 10.

So, as the researcher design, an IoT framework that manages run-time variability in senior high schools of connected objects, below is the structural view and outline of the

methodological steps to be considered in the framework design process as shown in figure 10.

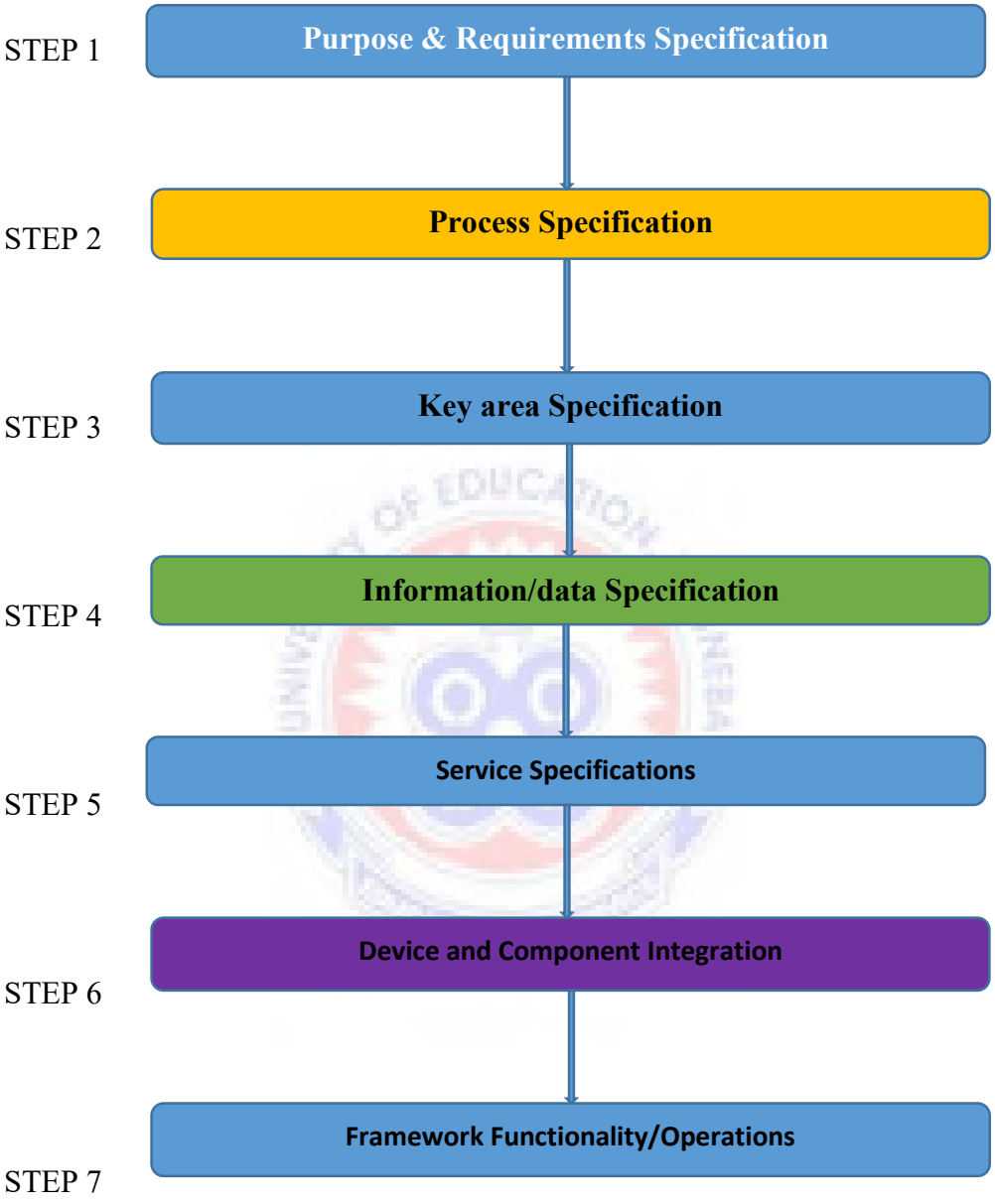

Figure 10: Methodological Steps of IoT framework Design (Bahga & Madisetti, 2015)

3.2.1. Step 1 (One): Purpose & requirements specification

The first step in this IoT framework design methodology is to define the purpose and requirements of the framework design. Here, the design purpose, behavior, and

requirements (such as interview, data, and analysis requirements, the framework management requirements, data privacy and security requirements, user interface requirements) are key elements to be captured within this stage.

According to Asmaa et al, (2017), the system's requirements can be identified as follows;

Smart proactive self-adaptation: the platform should provide the necessary mechanisms to analyze collected data and adapt the system in problematic situations.

Uncertainty management: the platform is required to evaluate the qualities the system offers in comparison with the ones requested by users.

Variability management: variability of the connected devices can be captured and managed at different levels.

Physical abstraction: the platform should support communication with heterogeneous devices and various technologies in order to monitor and actuate.

3.2.2. Step 2 (Two): Process specification

The second step in the IoT framework design methodology is to define the process specification involved. In this step, the use cases (main actors of the design system) of the IoT framework are formally described based on and derived from the purpose and requirement specifications that will be adapted for implementation.

3.2.3. Step 3 (Three): Key area specification

The third step in the IoT framework design methodology defines the key areas within the school where the system will be implemented. It is important to note that the specifications in this step describe the main areas that are central to the framework designed. These include classroom, administration block, dormitory, logistics/stores, library unit, laboratories, school bus, school fence, and parents.

3.2.4. Step 4 (Four): Information/data specification

The fourth step in the IoT design methodology is to define the data/information gathering process, structure attributes in relation to the framework design. Information about the virtual entities (key areas of the framework design) is defined to ensure a well interactive framework that can collectively work together. Library (books, computers, hardware materials, etc.), laboratories (computers, projectors, printers, etc.), classroom (whiteboard, furniture, teaching and learning materials, etc.). This information adds up more details to the various entities by defining all the various attributes for an easy design framework.

3.2.5. Step 5 (Five): Service specifications

The fifth step in the IoT design methodology is to define the main services that the IoT framework will be designed to perform in our schools. The service specification of the framework are defined as follows;

Service types describe the kind of activities/services that will be offered within the IoT framework operations by each IoT implemented area.

Service inputs describe the various elements that are located within the various IoT units in the school environment which are serving as actors of the system in that particular IoT sector.

Service schedules are a description of the operational periods for each IoT implemented environment. Whether the system is performing a run-time or periodic services for all the IoT sectors and or not.

Service effects are the leading operational abilities that the framework is expected to perform in the school. Table 3 below is the summary of the service specification.

Table 1: IoT Service Specification

IoT Functional Area	Service Type	Service Inputs	Service Schedules	Service Effects
Classroom	Teaching and learning activities Digital invigilation	Smart whiteboard Surveillance cameras Smart door etc.	During the schooling period	Checking attendance Monitoring teaching and activities
Administration Block	Monitoring and control activities	Surveillance cameras Detecting devices Sensors, computers.	All-round services	Produce reports Detect errors and control services Monitoring activities
Dormitory	Property protection	Surveillance cameras Sensors Automated bells	During the schooling period	Detect stealing Prevent property destruction
Laboratories	Teaching and learning activities Property protection	Surveillance cameras Projector Smart whiteboard	During the schooling period	Monitoring activities
Logistics/Stores	Stock surveillance	Surveillance cameras	All-round services	Monitoring activities
Library	Books and property protection	Surveillance cameras Library card logs	During the schooling period	Monitoring activities
School Bus/Vehicle	Transportation	GPS System, sensors Surveillance cameras	All-round services	Monitoring, Report and maintenance activities
IoT Fence	Checking for illegal entry through walls	Surveillance cameras Wall sensors/alarms	All-round services	Monitoring activities
Parents	Monitoring	Mobile devices	During the schooling period	Tracking and contact activities

3.2.6. Step 6 (Six): Device and component integration

The sixth step in the IoT framework design methodology is the integration of well-defined devices and components (such as, service hosting options, storage options, enabling devices options, operational devices, etc.) that will interact through network connectivity to function as a single technology in our senior high schools of Ghana. In the building of the framework designs, some of the devices and existing technologies that can support the framework operations are shown in table 4 below.

Table 2: IoT Devices and Components

IoT Devices	**Mobile Technologies, Bluetooth, Sensors, Connecting Wires, Computers, Cameras, Actuators, etc**
Existing Technologies	Radio Frequency Identification (RFID), Internet Protocol (IP), Electronic Product Code (EPC), Wireless Fidelity (Wi-Fi), Bluetooth, Zig Bee, Near Field Communication (NFC), Actuators, and Wireless Sensor Networks (WSN)

3.2.7. Step 7 (Seven): Framework functionality/operations

The seventh step in the IoT design methodology is to define its basic functionality and interactions among the various key areas of implementation. This step defines the main functions of the IoT framework in key areas/sectors of operation. It is an indication that the various functional groups provide interrelated functionalities that aid communication and device connectivity within the system as described below;

Authorities/Administration

In the proposed framework design in figure 11 below, Authorities/Administration serves as a central base where all the other key areas are directly monitored and control. The school Head/Vice at their comfort can gain access to data reports of all kinds from

the various units. IoT technology within the administration can help school authorities to perform the following functions;

- Track the movement of the school vehicle and its performance.
- Monitor classroom performance/activities in terms of teaching and learning, students and teacher attendance, and invigilation of examinations in the class.
- Heads and senior housemasters/headmistresses can equally monitor students directly at their dormitories.
- School authorities can also monitor the school library, stores, fence, and student movement directly on campus.
- Finally, reports of the various units can be generated for decision-making purposes.

School Library

The presence of surveillance cameras will serve as a checking tool for good library management. Authorities and Librarians can use the IoT technology for implementing library card logs, check-in systems, monitoring books and students in the library, including other materials in the library environment and at the time be able to generate library reports for decision making.

Logistics/stores

The stores serve as the warehouse for almost all senior high schools in Ghana, hence procured products and materials will be well monitored and be under proper surveillance due to the IoT technology for safekeeping. Again, authorities will have direct access or surveillance of whatever that happens in the logistics unit as indicated in figure 11 below.

School laboratories

The school laboratories are center for computer and science practicals and at the same time serve as a safekeeping center of laboratory materials for teaching and learning. Hence, an IoT framework for SHS will help in easy monitoring of teaching and learning activities in the laboratory, with continuous surveillance on laboratory properties.

IoT Fence

The IoT fence is a description of how the school fence with an IoT technology can be used to monitor the movement of students and visitors. Implementing IoT on a school fence will help to detect and deter truant students from running out of school through walls without exeat. So, this technology will offer school authorities and parents the ability to easily detect and monitor directly on students, visitors, and or strangers who may try passing through an illegal route of entry.

Parents

This proposed IoT technology in figure 11 below that may be adopted in schools will not be in isolation without the participation and involvement of parents. Parents as key stakeholders in our various schools will have the chance to;

- Track the movement of the school vehicle for students to be well satisfied with their ward's safety and movement schedules in and out of the school environment.
- Track or monitor the teaching and learning activities of their wards in the classroom for surety of active classroom work of their wards.
- To be contacted by school authorities directly on matters of concern about their wards (especially on sickness alert, academic concerns, meetings, and students who are officially or unofficial out of campus). In a nutshell, parents will have

direct information on their wards at school through the vehicle tracking system, classroom monitoring, and contact by school authorities.

Smart vehicle

School vehicles or buses are responsible for transporting students and teachers for academic competitions, sports and culture, excursions, and other school-based activities. Because of this key role of the transport system, school authorities and parents are therefore much concern about whatever that happens within the unit. So, IoT technology (like GPS tracking system, sensors, surveillance cameras, speed control systems, etc.) on school vehicles will help school authorities and parents;

- To be able to easily track the movement of the driver.
- To be able to monitor and as well as direct for safety route where necessary.
- To prepare the movement and maintenance schedule for drivers to follow in their journeys.
- To be easily be updated on the state of the vehicle routine activities based on the movement report.

In the smart vehicle system, only school authorities and parents have direct monitoring contact.

Smart classroom

In an IoT classroom, academic activities are a self-adaptive, more interactive, and content plan-driven outline. In the IoT set up the classroom environment will be installed with interactive whiteboards, smart doors, surveillance cameras and other e-gargets that will help aid;

- The checking of attendance of both teachers and students via the digitized smart door technology.

- Understanding and promote learning outcome through various electronic learning gargets
- Direct monitoring of classroom activities by authorities at their own comfort.
- Students' safety in cases of emergency and at the same time promote digital invigilation for examinations.
- The automation of academic schedules in classrooms as a way of proper time management.

3.3 Proposed IoT Framework Design for SHS in Ghana

The review of literature discussed extensively on various IoT designs ranging from the general IoT architecture, models, and various IoT smart campuses and environments by different scholars. Based on the analysis and development of these framework models, the researcher has been able to come out with a proposed IoT framework design for use by senior high schools in Ghana as shown in figure 11 below.

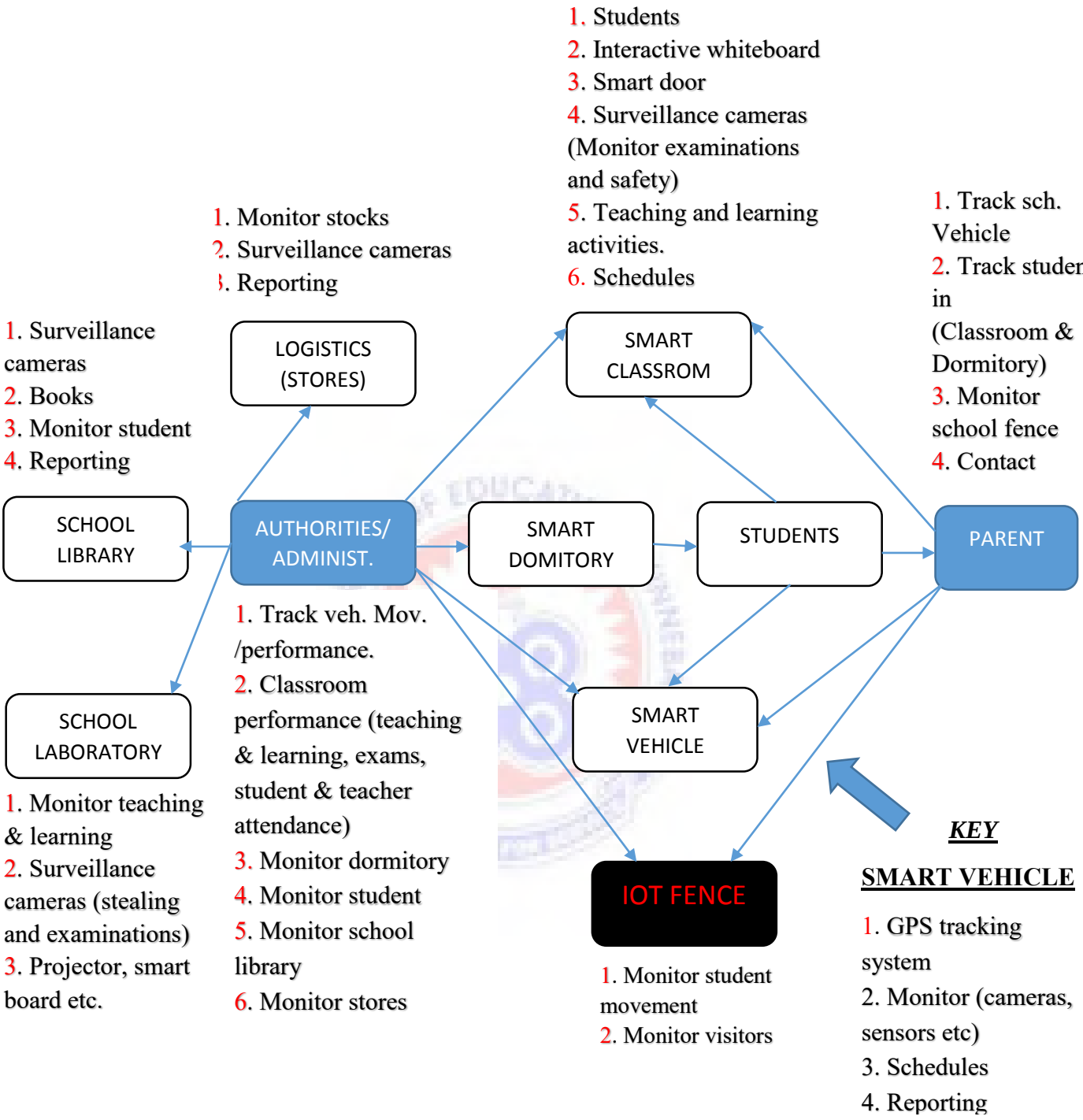

Figure 11: IoT Framework Design for SHS in Ghana

As discussed earlier, the main areas of this IoT implementation are the administration block, classroom, dormitory, laboratory, logistics/stores, library, school fence, and vehicles. Successful implementation of this framework proposed in figure 11 above will help in achieving the desired/target goal of preventing student kidnapping, school fraudster activities, students leaving school without exeat, scaling of school walls, digital invigilation, stealing and as well as used for administrative monitoring activities of Staff, students, and visitors in schools.

3.4 Software Tools Required for the Proposed Framework Design

To demonstrate the operability of the proposed framework, a simulation environment was created using the following software tools:

- Instant Contiki
- Cooja Simulator
- Virtual Machine (VM) ware
- Windows 10 and Ubuntu operating systems and
- C programing language

3.4.1 Instant Contiki

Contiki is an open source operating system that runs on tiny low-power microcontrollers and makes it possible to develop applications that make efficient use of the hardware while providing standardized low-power wireless communication for a range of hardware platforms. Contiki is used in numerous commercial and non-commercial systems, such as city sound monitoring, street lights, networked electrical power meters, industrial monitoring, radiation monitoring, construction site monitoring, alarm systems, remote house monitoring, and so on.

3.4.2. Cooja Simulator

Cooja Simulator is a cross-layer java-based wireless sensor network simulator distributed with Contiki. It allows the simulation of different levels from physical to application layer, and also allows the emulation of the hardware of a set of sensor nodes. Wireless Sensor Networks (WSNs) can be deployed using available hardware and software. The Contiki is an operative system compatible with a wide range of WSN hardware. A Contiki development environment named InstantContiki includes the Cooja simulator, useful to test WSN simulation scenarios prior to their deployment. Cooja can provide realistic results since it uses the full Contiki's source code and some motes can be emulated at the hardware level.

3.4.3. VM Ware, Windows 10 and Ubuntu Operating Systems

Instant Contiki is developed to run on Ubuntu operating system. This requires computers running on windows and other operating systems to create a virtual platform for the instant contiki using the VM ware or any other suitable platforms. Additionally, Cooja has an ipv6 addressing standard inbuilt using C programming and con be reconfigured to suit the network designers needs.

3.5 Limitations of the Proposed Framework

The framework design is limited to senior high schools in Ghana and therefore may not be applicable to other business organizations due to some attributes that may be missing in this high school IoT framework design.

Again, in the design of the framework, no school environment was proven to be adaptable to the system since it was a general framework design. So, adaptability may vary from one school environment to another.

Finally, in considering the framework design and adoption material and system development cost may be a hindrance to its full applications in high schools of Ghana.

3.6 Conclusion

The chapter discussed the design methodology and outline of steps that were used in the framework design, the structural view of the methodological steps, and the actual proposed IoT framework design for senior high schools in Ghana.

CHAPTER FOUR

SIMULATION OF PROPOSED FRAMEWORK

4.1 Introduction

This chapter displays the simulation results of the proposed IoT framework design for high schools in Ghana in relation to the various IoT frameworks and models that were reviewed in this study. The simulation is a virtual representation that was used to test its validity.

4.2 Simulation Results and Discussions

Cooja has been proven to be an ideal tool for the simulation of RPL (Routing Protocol for Low-Power and Lossy Networks) in WSNs. The simulations demonstrate the proposed the framework for various senior high schools in Ghana.

4.2.1 Cooja Screen

The Cooja simulator welcome screen is shown in figure 12 below.

Figure 12: Cooja Simulator Screen

4.2.2 IoT Framework for Smart Vehicle Management

Figure 13 shows the proposed IoT framework for smart vehicle management. The simulation shows the network communications between the various and entitities. The parants and other stakeholders (green motes) in the monitoring team can send and receive details of the vehicle (orange mote 7) movements as discussed in chapter three. The simulation verifies the proposed theory as discussed.

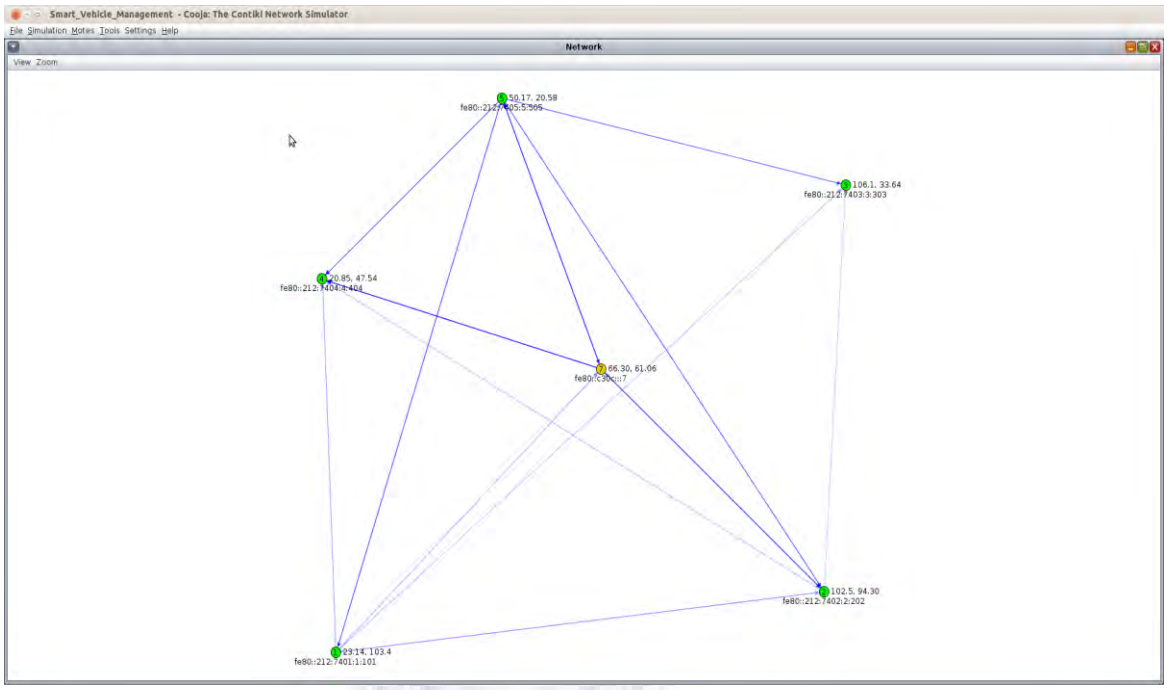

Figure 13: IoT Framework for Smart Vehicle Management

4.2.3 Simulation Demonstration with IPv6 Addressing

A complete simulation environment for cooja simulation is shown in figure 14. In the simulation, a mote represents a sensor node with it's network coverage and the location of other devices that can interfere with it's operation.

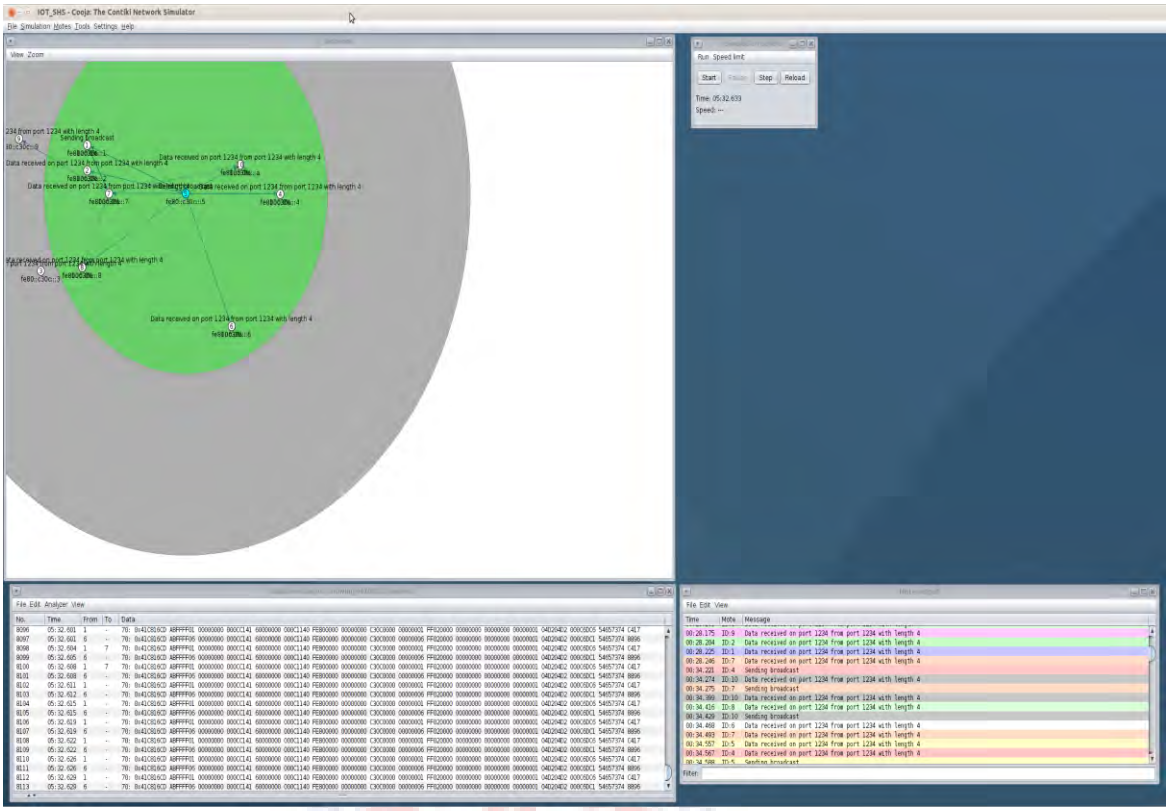

Figure 14: Simulation Demonstration with IPv6 Addressing

4.2.4 Mote Network and Interference Coverage

The simulation network shown below displays the transmission range of any particular mote and is extremely useful when deciding upon the optimal position of motes within a simulated network. The selected mote indicates the network coverage and interference area, which is the green and grey areas respectively. There are 10 devices in this network which communicate wirelessly with one another. Adjacent devices communication can affect the performance of nearby communications which is usually referenced as interferers. Figure 15 also displays the port to port communication, the port the message is transmitted and the port receiving as well as monitoring the radio network's traffic.

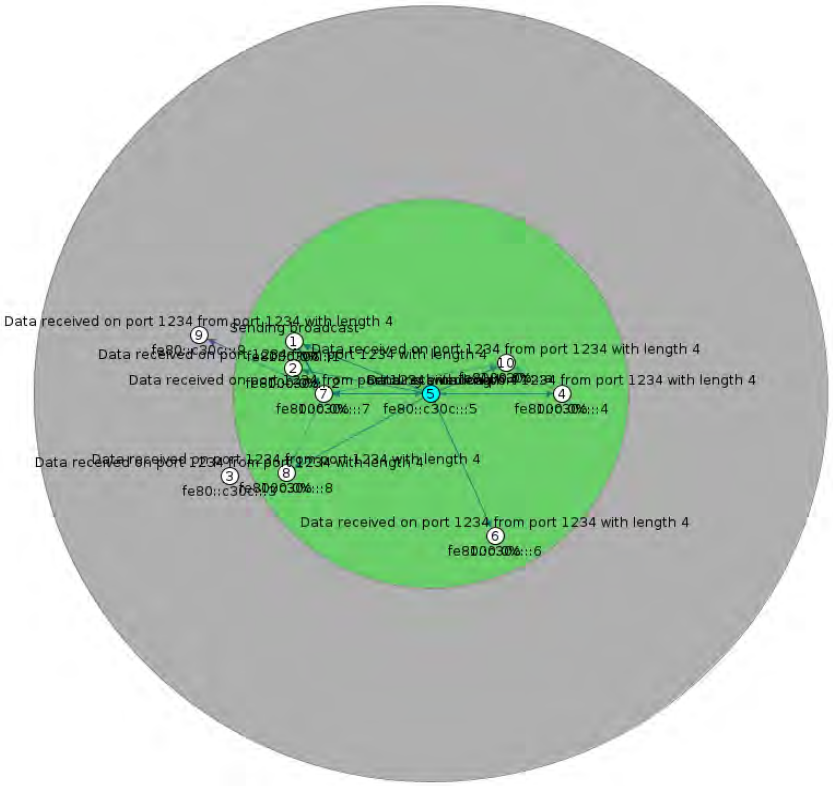

***Figure** 15: Simulation Network Coverage and Interference area*

4.2.5 Radio Messages Output

Radio messages output displaying radio messages of 6LowPAN packets, using 802.15.4 data in physical layer.

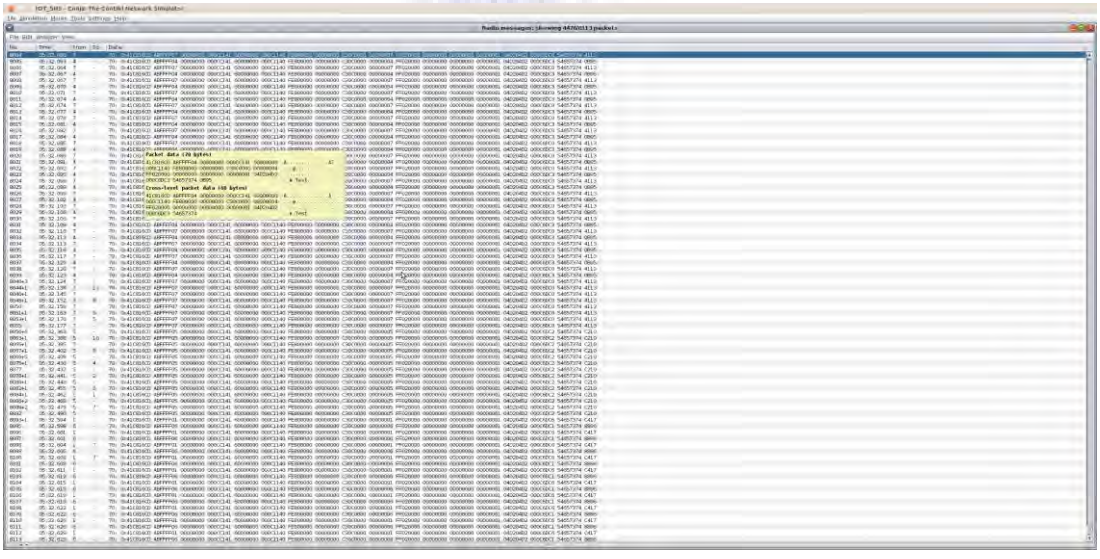

Figure 16: Radio Message Output

4.2.5.1 Samples of Detailed Messages from the radio Message Output

301914 8 - 64: 0x41C814CD ABFFFF08 00000000 000CC141 60000000 00063A40 FE800000 00000000 C30C0000 00000008 FF020000 00000000 00000000 0000001A 9B00A40C 00000D18
301918 8 - 64: 0x41C814CD ABFFFF08 00000000 000CC141 60000000 00063A40 FE800000 00000000 C30C0000 00000008 FF020000 00000000 00000000 0000001A 9B00A40C 00000D18
301921 8 5 64: 0x41C814CD ABFFFF08 00000000 000CC141 60000000 00063A40 FE800000 00000000 C30C0000 00000008 FF020000 00000000 00000000 0000001A 9B00A40C 00000D18
301924 8 - 64: 0x41C814CD ABFFFF08 00000000 000CC141 60000000 00063A40 FE800000 00000000 C30C0000 00000008 FF020000 00000000 00000000 0000001A 9B00A40C 00000D18
301928 8 - 64: 0x41C814CD ABFFFF08 00000000 000CC141 60000000 00063A40 FE800000 00000000 C30C0000 00000008 FF020000 00000000 00000000 0000001A 9B00A40C 00000D18
301931 8 - 64: 0x41C814CD ABFFFF08 00000000 000CC141 60000000 00063A40 FE800000 00000000 C30C0000 00000008 FF020000 00000000 00000000 0000001A 9B00A40C 00000D18

4.2.6 Mote Output

Mote output gives the time for each mote communication, mote ID, and Messages from one mote to another mote. The details view of the motes ouput with the client and server relationships are ahow below in figure 17.

Figure 17: Mote Outputs

4.2.6.1 Mote Output Details

```
00:00.887       ID:8    Rime started with address 193.12.0.0.0.0.0.8
00:00.900       ID:8    MAC c1:0c:00:00:00:00:00:08 Contiki-2.6-900-ga6227e1 started.
Node id is set to 8.
00:00.908       ID:8    CSMA ContikiMAC, channel check rate 8 Hz, radio channel 26
00:00.921       ID:8    Tentative link-local IPv6 address
fe80:0000:0000:0000:c30c:0000:0000:0008
00:00.925       ID:8    Starting 'UDP broadcast example process'
00:01.051       ID:2    Rime started with address 193.12.0.0.0.0.0.2
00:01.063       ID:2    MAC c1:0c:00:00:00:00:00:02 Contiki-2.6-900-ga6227e1 started
Node id is set to 2.
00:01.065       ID:6    Rime started with address 193.12.0.0.0.0.0.6
00:01.072       ID:2    CSMA ContikiMAC, channel check rate 8 Hz, radio channel 26
00:01.077       ID:6    MAC c1:0c:00:00:00:00:00:06 Contiki-2.6-900-ga6227e1 started.
Node id is set to 6.
00:01.084       ID:2    Tentative link-local IPv6 address
fe80:0000:0000:0000:c30c:0000:0000:0002
00:01.086       ID:6    CSMA ContikiMAC, channel check rate 8 Hz, radio channel 26
00:01.089       ID:2    Starting 'UDP broadcast example process'
00:01.099       ID:6    Tentative link-local IPv6 address
fe80:0000:0000:0000:c30c:0000:0000:0006
00:01.103       ID:6    Starting 'UDP broadcast example process'
00:01.163       ID:4    Rime started with address 193.12.0.0.0.0.0.4
00:01.175       ID:4    MAC   c1:0c:00:00:00:00:00:04   Contiki-2.6-900-ga6227e1   started.

Node id is
```

4.3 Benefits of the Proposed IoT Framework Design

4.3.1 Prevention of student kidnapping and fraustering activities in schools

The presence of IoT framework in our schools will serve as the germ to the total elimination of the recent student kidnapping and fraustering activities by criminals in our society. It will help school administrators and parents to be sure and confident of student safety within the school environment.

This canker of kidnapping is currently a serious challenge to every Ghanaian citizen and can be better eliminated within our school setting through this 24hour surveillance internet of things technology. Hence, this IoT framework technology will be more beneficial to all educational organizations since it will help to reduce the burden of ineffective human security services.

4.3.2 Effective Monitoring and Supervision

Internet of things in senior high schools will serve as a tool for bridging the gap of monitoring and supervision lapses that are predominant in all educational institutions. School administrators are faced with supervision and monitoring challenges on the part of staff and students thereby hindering the success and productivity level of schools. The chunk of resources that educational stakeholders and supervisors invest in schools can be drastically reduced through the magic and adoption of IoT framework.

This framework will offer administrators and supervisors a cost effective, efficient and effective monitoring and supervision activities at their own comfort, anywhere and at any time through the use of internet of things technology. Generally, IoT framework is the solution to low productivity levels at schools, high cost of monitoring and supervision, ineffective monitoring and supervision strategies and the waste of human and material time and resources.

4.3.3 Improve Instructional Strategy and Academic Performance

Internet of things framework in schools will provide a lot of benefits by improving the instructional strategies of teachers and academic performance of students through the use of various technological media. Internet of things technology in the classroom is beneficial in the teaching and learning process as a results of;

- The presence of many instructional media for use in the teaching and learning process (including projectors, smart boards, audio media, audio-visual devices etc).
- Flexible teaching and learning activities where the learning process is dynamic and always directed towards the ability of learners.

- Multiple instructional strategies including game-based learning, simulation and modeling, computer base training, group drill and practice etc.
- Unlimited e-teaching and learning resources available to both students and teachers for improved teaching strategies and academic performance.

4.3.4 Improved security and surveillance system in schools

IoT will help to improve the security and surveillance system in our senior high schools through an intelligent IoT collaborative educational ecosystem that enhances a 24hour security surveillance within the school environment, hence preventing criminal activities and assuring parents of their children safety. Again, because of the high security and surveillance systems school properties will be save from the hands of thieves and criminals, thus preventing recurring cost and huge properties expenditure from government.

4.3.5 Prevent invigilation challenges during examination

The adoption of IoT framework technology will equally help to reduce the cost of hiring several invigilators, prevent cheating in examination halls and check impersonation during examinations through the use of biometric check-in for candidates. Internet of things technology will only demand few supervisors for monitoring and supervision purposes, hence can serve as an effective and efficient technology to be adopted by examination bodies (WAEC) and schools for both internal and external examinations.

4.4 Comparison of the Traditional and IoT School Environment

The below table 3 compares the traditional school environment to an IoT school environment in order to show the vast and enormous reasons and benefits of this IoT framework if implemented in schools as compared to others.

Table 3: Comparison of Traditional and IoT School Environment

Nature of Traditional School Environment	Nature of IoT School Environment
Require human resources for spreading education.	Delivery of education through digital media.
Needs physical attendance of both teachers and students, which sometimes leads to proxy.	Lessons/classes can be automated to prevent any form of proxy.
Limited teaching and administrative resources available.	Availability of multiple teaching and administrative resources.
Numerous challenges during examinations including exams malpractice, invigilation challenges etc.	Digital invigilation is the solution to this numerous examination challenges.
Physical/manual monitoring activities in schools.	Digital monitoring of teaching and administrative activities in schools.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDTIONS

This chapter will cover summary of the research study, conclusions from the study, recommendations and suggestions for future research.

5.1 Summary of the Study

The study aims to design an IoT framework for senior high schools in Ghana. This fast-emerging technology is a resourceful tool that is gaining much attention in most organizations including the educational sector. So, in trying to find a lasting solution to the numerous challenges in our senior high schools, the researcher proposed the design of an IoT framework that will greatly help stakeholders and school administrators to better manage, control, monitor, and supervise operational activities of schools with effective and efficient devices. Hence, all activities in this study are geared towards achieving this goal of averting the numerous challenges that senior high schools face in Ghana.

The study also carefully reviewed the literature on IoT framework design, IoT implemented areas, the benefits of the internet of things in education, and conceptual and theoretical review of the research problem. All this critical review was done in order to gather factual evidence in support of the research problem and how a general acceptable IoT framework can be designed for high schools in Ghana.

The study also outlines design methodological steps, structural view of these steps and tools that serve as the basis for the framework design. It is fast revealing that the researcher studied all the IoT frameworks and models considered in this study to finally come out with a general framework design that captures key areas of senior high

schools' operational management. The study also discussed and produced a simulation of the framework design for high schools in Ghana in relation to the several frameworks and models reviewed in chapter two. Hence, the study reveals that this emerging technology (IoT framework) will become the solution to the numerous challenges in organizations more especially the educational sector in Ghana.

5.2 Conclusion

The research was concentrated and directed on the design of an IoT framework for senior high schools in Ghana. The researcher, therefore, considered several IoT frameworks and models as the benchmark for designing a well acceptable IoT framework for use in senior high schools of Ghana. Thus, the researcher is confident to conclude that this IoT framework design will be a lasting solution to the numerous challenges school administrators encounter in high schools.

5.3 Recommendations

This part of the research outlines the various guidelines and activities that designers and school administrators need to consider in the design and adoption of this IoT framework for senior high schools in Ghana.

Firstly, to produce a more acceptable design, framework designers need to give critical attention to requirement gathering and specifications for the various sectors to be included in the design structure.

Secondly, framework designers need to consider the adaptability and compatibility of both hardware and software components of the design to the school environment. In cases of incompatibility, the intended purpose of the framework design will not be achieved.

Thirdly, framework designers need to also consider cost-effective, efficient, and durable devices that will stand/last the test of time with purposefulness and efficiency. Also, school administrators and framework operators need to be cautious and ensure the maintenance of the system to last the period of time.

Finally, stakeholders of our educational system should be educated on the enormous benefits of this internet of things framework design for senior high schools and at the same time be encouraged to adopt this fast-emerging technology of our time.

5.4 Suggestion for Future Research

It is my humble wish and hopes that anyone or researcher who lay hands on this piece of work should be motivated to research/improve upon its weakness and other essential areas that further research can be conducted on.

While much effort is concentrated and directed towards the design of an IoT framework for senior high schools, there has been little research on the security and privacy issues of IoT technology. Therefore, further research can be conducted on IoT security and privacy issues to ensure a well-secured IoT design.

Also, further research can be conducted on user opinions to create awareness and educate end-users about this emerging IoT technology and how objects (things) around us can be connected to be sensitive and useful to mankind.

REFERENCES

Amr, E., & Mohamed, S. (2017). *Experimental Evaluation of Internet of Things in the Educational Environment,* 7(3), 53. Published by Authors 30th July, 2017.

Asmaa, A., Nissrine, S., Raul, M., Camille, S., & Ounsa, R. (2017). Designing a Framework for Smart IoT Adaptations. *ResearchGate*.

Bahga, A., & Madisetti, V. (2015). *Internet of Things*. Retrieved from Internet of things: http://www.internet-of-things-book.com. Arshdeep Bahga and Vijay Madisetti publishers.

Bannon, L. (1997). *Activity theory.* Retrieved from www.irit.fr: http://www.irit.fr/ACTIVITES/GRIC/cotcos/pjs/TheoreticalApproaches/Actvity/ActivitypaperBannon.htm.

Buyya, R., & Dastjerdi, A. (2016). *Internet of Things Principles and Paradigms,* (1st ed.). Todd Green publication.

Carroll, J., & Rosson, M. (2003). *Design Rationale as Theory, in HCI Models, Theories and Frameworks: Toward a Multidiciplinary Science (Interactive Technologies).*

Chang, H. C. (2011). Smart classroom roll caller system with IoT architecture. *2011 Int. Conference of Innovation and Bio-Inspired Computer Application* (IBICA), 356-360.

Cisco Systems. (n.d.). *Cisco Systems*. Retrieved from The Internet of Everything: Fueling Educational Innovation.

Dave, E. (2014). Internet of Things Reference Model. Retrieved from *Cisco Systems*.

Elyamany, H. F. & Alkhairi, A. H., "IoT-academia architecture: A profound approach," *2015 IEEE/ACIS 16th Int. Conf. Softw. Eng. Artif. Intell. Netw. Parallel/Distributed Computer. SNPD 2015 - Proc.*, 2015.

Evans, D. (2011). T*he Internet of Things:* How the Next Evolution of the Internet is Changing Everything.

Friess, P. (2013). *Internet of things: converging technologies for smart environments and integrated ecosystems*: River Publishers.

Gibson, J. (1986). The Ecological Approach to Visual Perception. Lawrence Erlbaum Associates, Inc. (originally published in New York: Houghton Mifflin, 1979).

Gubbi, J., & Buyya, R. (2013). Internet of Things (IoT): A vision, architectural elements and future directioons. *Future Generation Computer Systems*, 1645-1660. Retrieved April 27, 2019, from http://www.sciencedirect.com/science/article/pii/S0167739X13000241

Gupta, A., & Fisher, D. (2012). Technology-supported learning environments in science classrooms in India. *Learning Envrion Res*.

Images for pinterest.com. (n.d.). *pinterest.com*. Retrieved from pinterest.com: https://www.pinterest.com/pin/420453315183452859/

ITU-T. (2012). *Global Standards Initiatives Recommendation*. Retrieved May 2019, from Global Standards Initiatives Recommendation: http://www.itu.int/en/ITU-T/gsi/iot/Pages/default.aspx.

Johnson, L., Becker, S., Estrada, V., & Freeman, A. (2015). *The NMC Horizon Report.* Austin: The New Media Consortium.

Kaptelinin, V., & Nardi, B. (1997). *Activity theory:* basic concepts and applications, in CHI '97 extended abstracts on Human factors in computing systems: looking to the future. 158-159.

Kiryakova, G., Yordanova, L., & Angelova, N. (2017). Can we make schools and universities smarter with the Internet of Things? *TEM Journal, 6*(1), 80-84.

Kortuem, G., Bandara, A., Smith, N., Richards, M., & Petre, M. (2013). *Educating the Internet of Things Generation. ResearchGate*.

Kothari, C.R. (2004). *Research methodology methods & Techniques.* Published by New Age International (P) Ltd., Publishers.

Leochner, J. (2015). Internet of Things' Connected Devices to Almost Triple to over 38 Billion Units by 2020. *Juniper Research*.published by MediaPost Communications.

Maksimović, M. (2017a). Transforming educational environment through Green Internet of Things (G-IoT), *Trend 23*, 32-35.

Maksimović, M. (2017b). Green Internet of Things (G-IoT) at engineering education institution: the classroom of tomorrow, *INFOTEH-Jahorina 16*, 270-273.

Marquez, J., Villanueva, J., Solarte, Z. & Garcia, A. (2016). *"IoT in Education: Integration of Objects with Vitual Academic Communities*," New Adcances in Information Systems and Technologies, no. 115, Spinter International Publicatins, 201-212.

Mitew, T. (2014). Do objects dream of an internet of things? *The Fibreculture Journal: Digital Media + Networks + Transdisciplinary Critique, 23.* Retrieved from http://fibreculturejournal.org/wp-content/pdfs/FCJ-168Teodor%20Mitew.pdf.

Mohanapriva, M. (2016). *IoT-enabled futurus smart campus with effective E-Learning: i-Campus, 3*(4), 81-87.

Nie, X. (2013). *Constructing Smart Campus Based on the Cloud Computing Platform and the Internet of Things.* Paris: Atlantis Press.

O'brien, J. (2016). *The Internet of Things in Higher Education, 51*(4). educause. Published by D.Teddy Diggs

Papert, S. (1986). *Constructionism: A New Opportunity for Elementary Science Education.* A proposal to the National Science Foundation.

Sethi, P., & Sarangi, R. (2017). Internet of Things: Architectures, protocols and applications. *Journal of Electrical and Computer Engineering*. Retrieved from http://dx.doi.org/10.1155/2017/9324035.

Stankovic, J. A. (2014). Research directions for the internet of things. *IEEE Internet of Things Journa*l, 1(1): 3-9.

Teodor, M. (2014). Do objects dream of an internet of things? *The Fibreculture Journal*. Retrieved from http://fibreculturejournal.org/wp-content/pdfs/FCJ-168Teodor%20Mitew.pdf.

UNESCO. (2017). *Educating for a sustainable future*. Retrieved from unesco.org: http://www.unesco.org/education/ tlsf/mods/theme/popups/mod01t05s01.html#edu.

Vermesan, O., & Friess, P. (2014). *Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems.* River Publishers.

Vujovic, V., & Maksimovic, M. (2015). The Impact of the Internet of Things on Engineering Education. *The 2nd International Conference on Open and Flexible Education (ICOFE)*, Hong Kong: 135-144.

X-systems.com. (n.d.). *Mobile iot security solutions*. Retrieved from x-systems.com: https://x-systems.com/mobile-iot-security-solutions/education.