The Potential of IoT on the Education Sector in Zimbabwe: The Case of University of Zimbabwe

Farai Francisco Madyira
University of Zimbabwe School of Technology
University of Zimbabwe
Harare, Zimbabwe
madyiraff@gmail.com, fmadyira@uz.edu.zw
Barend W Botha
University of Johannesburg
Johannesburg, South Africa
bwbotha@uj.ac.za

Abstract

The Internet of Things (IoT) is a technological trend or development that is changing the world in several amazing ways. It is a technological trend or development that developing countries such as Zimbabwe can adopt to jumpstart their economies so as to improve the welfare of their populations. This technological trend has expeditiously captivated the global attention with business organisations, academia and governments assigning high priority to them. Reviewed literature shows that most developed economies have embraced and implemented IoT technologies in tertiary education institutions resulting in the improvement of the learning experience and management of resources, an opposite characteristic of developing economies such as Zimbabwe which still lag behind with regards to technological stature of institutions of higher learning. The focus of this paper is to explore the potential that IoT holds for the tertiary education sector in Zimbabwe. The study develops a framework to harness the power of IoT in Zimbabwe's education sector that institutions of higher learning can adopt in their quest to drive the nation's socio economic development. This is achieved through the exploration of a case study (University of Zimbabwe) on the feasibility, possible adoption options and how this enhances the return on the ICT investments already made on the existing ICT infrastructure. The case study analysis process undertaken sheds more light on both positive and negative factors that require consideration when IoT is set to be implemented in the education sector. A framework for the adoption was developed and recommendations rendered.

Keywords (12 font)
Internet of Things, Industrial Internet of Things

1. INTRODUCTION

The world has for decades been experiencing changes which affects and dictates the way production of goods and services is realised as well as the way they are consumed by both business organisations and individuals. Some of the recent changes are attributable to the use of the Internet that transformed the way computer systems are utilised by both individuals and business organisations and how they interact (Kalle & Rose, 2003). Since its inception, the Internet has evolved significantly thereby paving way for greater functionality for both individuals and business organisations. This evolution has necessitated the acquisition and dissemination of information and/or data across the globe as well as the facilitation of collaborative efforts amongst individuals and groups irrespective of geographic location. As a result, this laid a solid foundation which supported the birth of the phenomenon referred to as the Internet of Things (IoT) that triggered the evolution of the global economy, a characteristic commonly known as the fourth industrial revolution, a revolution deeply rooted in the concept of Industrial Internet of Things (IIoT) (Boyes, Hallaq, Cunningham, & Watson, 2018). These two concepts (IoT and IIoT) have expeditiously captivated the global attention with business organisations, academia and governments assigning high priority to them. As a result, several

model architectures were crafted to aid the implementation of both IoT and IIoT (Ning & Hu, 2011). The evolution of the industrial revolutions are illustrated in Figure 1.

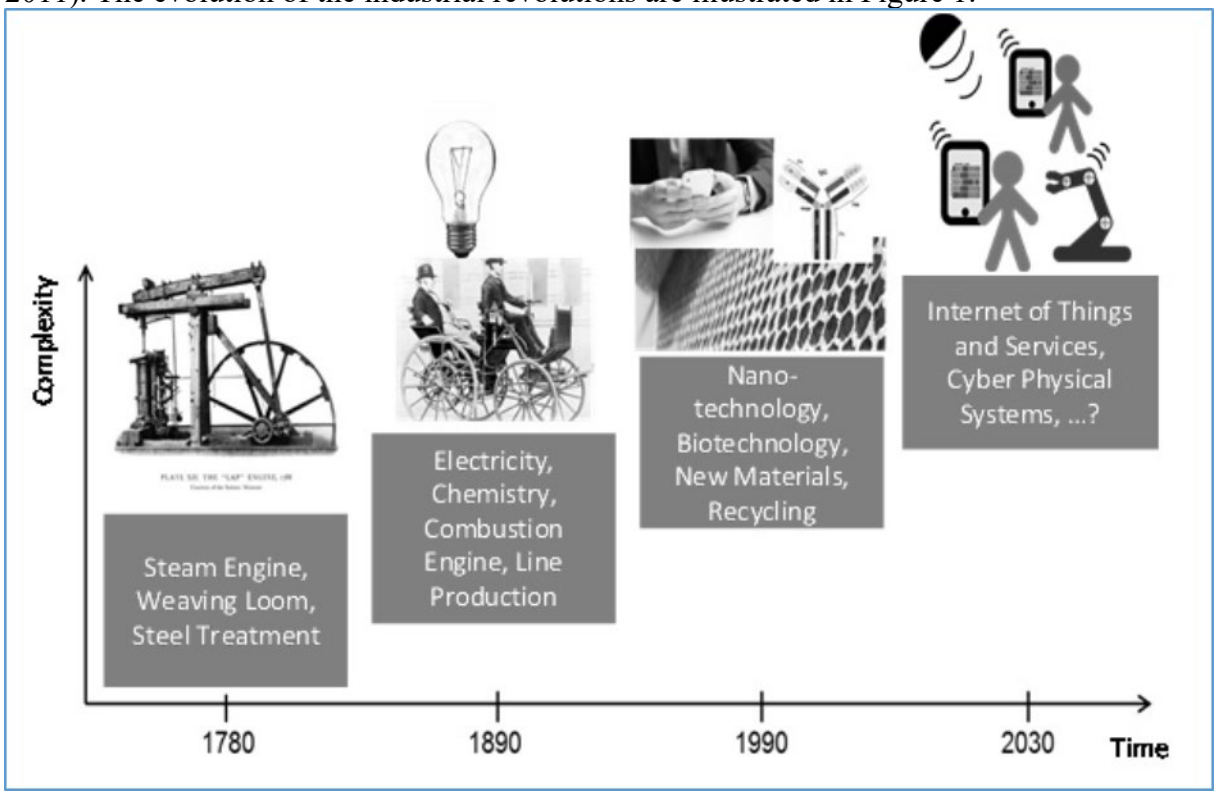

Figure 1: Chronological view on key-technologies of industrial revolutions (Adopted from Dombrowski and Wagner (Dombrowski & Wagner, 2014))

These industrial revolutions have over the years transformed the interaction between businesses, individuals as well as business organisations and individuals. The dynamics of the revolutions have also resulted in the development of technologies which gave birth to smart devices with architectures that support the generation of vast amounts of data as well as bearing capabilities of being interconnected. The interconnection and generation of large quantities of data (Big Data) characteristics as well as the availability of complex methods and capabilities of storing, including processing these large volumes of data, paved the way for the introduction of mechanisms that improve transparency, accountability, control, efficiency as well as effectiveness in the operations of both individuals and business organisations thereby enhancing the production of goods and services that are cost effective and affordable. The revolutions started decades back with three phases already passed. Currently, we are in the fourth industrial revolution also referred to as Industry 4.0 with some quarters preferring to call it the Industrial Internet of Things (IIoT).

This 4th industrial revolution is expected to bring further transformation to all sectors of the economy globally. The focus of this paper is therefore to present the potential that Zimbabwe and other similar economies are set to benefit from embracing IoT in their jurisdictions; paying special attention to the tertiary education sector of Zimbabwe. The paper begins by analysing global trends of IoT implementation and then cascades down to the Zimbabwean context. It then presents the global IoT trends in the education sector narrowing down to the tertiary education sector of Zimbabwe. The methodology that was adopted for the study is articulated. The case of

the University of Zimbabwe (UZ) is then adopted where current processes and ICT infrastructure are evaluated, analysed and the suitability of IoT implementation is discussed. The proposed IoT implementation framework at the UZ is then presented with the implications of the proposed migration discussed. At the end conclusions and recommendations are given.

2. INTERNET OF THINGS (IOT) AND INDUSTRIAL INTERNET OF THINGS (IIOT)

IoT insinuates a broad perception whereby "things", for instance conventional units, points and circumstances are interlinked to each other using the Internet. It is intelligently interconnecting smart entities and systems in order to collect data assembled by installed actuators and sensors in physical items and machines. This implies that IoT is the process of interconnecting ordinary items (or "things") which are organised and usually possess the omnipresent phenomenon (Kaur, Hans, & Singh, 2016). According to Perera (Perera, et al., 2015), IoT can be referred to as an interconnection of networks consisting of an enormous number of entities which may include but not limited to items, sensors, things and objects which are interlinked through Information Communication Technologies (ICTs) infrastructure with the objective of providing value addition to services. In this regard, it can be noted that IoT enables individuals and things to be associated at any moment regardless of location and circumstances, ideally utilising any data communication technologies and services. This entails that an ecosystem can be developed comprising of things interlinked together. The ecosystem can comprise of a connection to the Internet with the objective of acquiring and transmitting data and/or information with little intervention from people. This provides for the creation of an improved environment for people. It can be deduced from the given definition and explanations that connectivity of the gadgets is one of the key ingredients for the success of the IoT.

Therefore, IIoT is the application of the concept of IoT in an industrial setting such as manufacturing. The drive behind this concept is the notion that having smart industrial systems is more preferable than greater human intervention as they are more precise and consistent in the acquisition and dissemination of data and/or information with regards to business processes. This notion is further cemented by the fact that industrial processes and systems are evolving and becoming more and more complex as well as dangerous if mismanaged, hence the need for an efficient and effective mechanism to constantly monitor them. As a result of implementing IIoT, the business organisation is empowered with the ability to identify system inefficiencies and faults promptly thereby realising savings of the scarce resources which include, but are not limited to, time and finances. This triggers the process that result in the enhancement of organisational intelligence initiatives (Rouse, 2015). It can also be asserted that IIoT unites smart machines, progressed investigation and individuals in workplaces. It is an interconnection of a large number of gadgets linked together using data communication techniques. The resulting system has the ability to monitor, gather, trade, scrutinise and convey significantly new intuition in a unique manner (Lourie, 2017).

IIoT revolutionises activities associated with manufacturing by empowering the collection and availability of an enormous quantity of data, at very high velocities coupled with great efficiency compared to an era prior to IIoT implementation. Various creative business organisations have begun to put into effect IIoT by utilising smart, interlinked gadgets in their production lines. It is generally perceived that IIoT is one of the dominant trends influencing industrial organisations at this juncture and into the future (Inductive Automation, n.d.).

There exists a number of guides with regards to the implementation of IIoT. According to James Liu (Liu, 2017), IIoT architecture is composed of five broad components namely data collection, communication techniques, integration with the current data collection systems, cloud computing

and security. Data acquisition is one of the key elements of IIoT, hence the need to properly evaluate what needs to be collected and the sensors to be used in the collection. The data that is collected will have to be transmitted using communication technologies. In this regard, a determination has to be made with respect to the communication medium to be implemented, bandwidth requirement, the existence of wireless and wired technologies in the facility as well as the size of the facility paying special attention to the cost of implementation. It is also crucial that IIoT implementation enhances the organisation's performance by integrating the existing systems such as SCADA. Furthermore, cloud computing is incorporated to cater for storage requirements, complex analysis of data, and optimisation of network usage. Lastly, security should be implemented to protect both data and physical resources from unauthorised access. This is achieved through the development of security policies as well as defining controls and how they are executed.

Another similar IIoT architecture was put forward by Puri (Puri , 2016) with the assertion that it is composed of industrial control systems, gadgets, storage, processors, application channels, gateways, collectors, models, computing areas and security. In this architecture, there is the acknowledgement that the business organisation may be running industrial control systems (ICSs) such as SCADA that require integration into IIoT. Apart from ICSs to be integrated, the environment also has specialised industrial gadgets which include sensors, loggers and actuators. These collect data and/or information which is transmitted through communication technologies (i.e. channels and gateways) and the data and/or information destined for storage facilities. There also exist computing areas which may vary from one implementation to another and may include cloud computing, fog computing and hybrid computing. This architecture is diagrammatically illustrated in Figure 2.

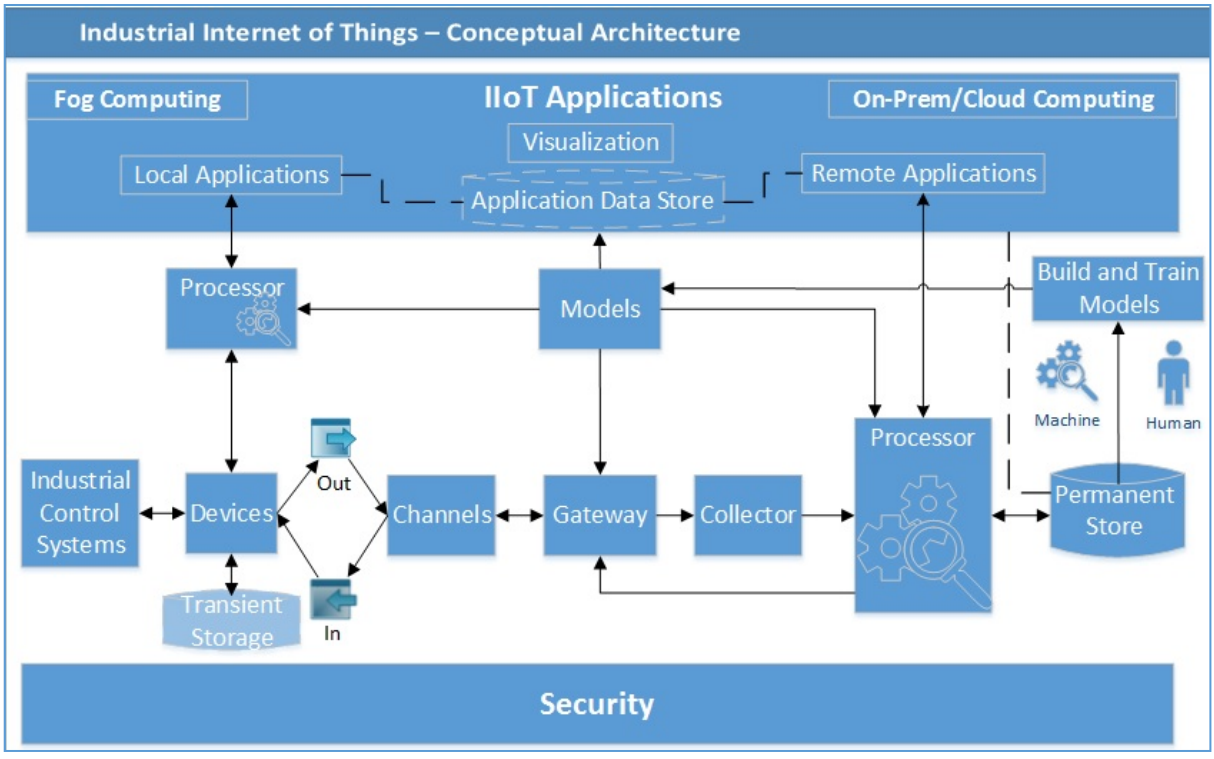

Figure 2: IIoT Architecture (Adopted from Puri (Puri , 2016))

2.1 IoT Implementation in Zimbabwe

Zimbabwe is one of the African countries making an effort to embrace IoT and IIoT. Although the uptake is still very low, there is evidence of the implementation of IoT in the Zimbabwean economy. In 2015, Econet Wireless Zimbabwe Holdings launched a car monitoring service which enabled business organisations and individuals to monitor their vehicle(s) remotely in real time. The connected car service was in 2016 joined by another intriguing IoT product from Econet Wireless Zimbabwe Holdings called ConnectedHome. The ConnectedHome service offers a number of services embedded on smart technologies which included, but were not limited to, smoke and gas detection, backup power source, indoor and outdoor motion sensors, camera surveillance, rapid response and forced entry detection (Gambanga, 2015). Later in 2018 Powertel Communications, one of Zimbabwe Electricity Supply Authority (ZESA) Holdings' subsidiaries, ventured into IoT implementation which resulted in the launching of new service lines which included monitoring of generators and tracking of vehicles. The decision to venture into IoT by Powertel was motivated by capabilities they discovered of IoT which include simplification of doing business, reduction in cost of operation, real time management and control of resources, reduction in abuse and pilferage as well as increasing productivity (Makopa, 2018). In early 2019, Powertel came to the rescue of its parent company ZESA holdings by introducing a system that monitors and manages transformers in real time as a solution to curb theft and vandalism of transformers which had become a scourge for the organisation. The intervention by Powertel is set to avert 4.5 million United States Dollars in losses that ZESA holdings was incurring as a result of the scourge, an amount that could be used to finance the upgrading of the country's electricity grid which is key for the development of the Zimbabwean economy (Mutisi, 2019).

3. GLOBAL IOT TRENDS IN THE EDUCATION SECTOR

The Internet through IoT has revolutionised the manner in which individuals collaborate and the education sector has not been spared by this development, which ushered in new models for collaboration between educators and scholars that improves the educating and learning system, and broadens the setting where scholars learn. This results in more interactive and captivating learning climate for scholars supporting the collection of large amounts of data pertaining to the process of learning which assists educators with the enhancement of their insights on the pace of learning of scholars and challenges they face (Marquez, Villanueva, Solarte, & Garcia, 2016). The educational institutions across the globe are stampeding in the adoption and implementation of IoT technologies on their campuses due to the realisation of the feasibility of application and immense benefits that can be accrued from such an initiative ((Bagheri & Movahed, 2016), (Sharma & Suryakanthi, 2015) and (Kalluri , 2017)). The adoption and implementation of IoT technologies in the education sector advances the transition of tertiary education. The transition affects issues which include, but are not limited to, training, management, experimentation, teaching, learning and education. In other words, IoT is revolutionising how tertiary education is perceived and delivered (Tianbo, 2013).

Several cases can be cited as evidence of the implementation of IoT across the globe. IoT is being used in fostering efficient utilisation of campus resources such as lecture rooms as implemented at Drenthe College in Netherlands which is being used to help students in finding potential meeting places for discussions (Gimbel, 2018). The University of New South Wales implemented IoT technology as a tool to aid monitoring the consumption of energy whilst The University of Washington uses this technology to gather information on buildings and power consumption. The gathered information is used in supervising Heating, Ventilation and Air Conditioning system (HVAC) systems and lighting networks ensuring optimum performance. Another intriguing example is that of the University of the Pacific which implemented IoT in the lecture rooms for the supervision of stance and non-verbal communication elements so as to measure how these relate to learning and commitment of students (Mitel Power Connections, 2018).

3.1 IoT and the Zimbabwean Education Sector

IoT technology adoption and implementation in institutions of higher learning in Zimbabwe is still a grey area. It is an alien concept which requires advocacy to be popularised so that it can get takers for adoption. It is hoped that the government policy (Science, Technology, Engineering and Mathematics (STEM)) will create an enabling environment that will see the uptake of the technology in education (Gandawa, 2016). This study is a first positive step towards popularisation as it develops an adoption framework for UZ, one of the leading institutions of higher learning in Zimbabwe. This will enable other institutions in the same sector and similar environments to learn from. Current literature has no evidence of work done on the adoption and implementation of IoT technology in tertiary education sector of Zimbabwe. This study sets a historical milestone as it creates a record for the Zimbabwean environment.

4. OVERVIEW OF UNIVERSITY OF ZIMBABWE

The UZ is the oldest government owned institution of higher learning in Zimbabwe and has its roots grounded in the pre-independence era around 1945 developing into the then University of Rhodesia and later becoming UZ after the attainment of independence in 1980 (Cheater, 1991). It was established in 1983 through the UZ Act (Chapter 25:16). It consists of ten (10) faculties with a complement of about five thousand (5000) members of staff established to serve an enrolment of over twelve thousand (12000) students seeking undergraduate and postgraduate certificates, diplomas and degree qualifications. Students' enrolment is drawn from all provinces of the country with minority small percentage () coming from some countries in the African region. The university's existence is anchored on the provision of high calibre and novel tertiary education, research, training and value in accordance with the needs of its clients so as to significantly contribute towards sustainable advancement in both social and economic spheres. The ultimate stature of the university is to become the prime institution of innovation in tertiary education and research with the capability of providing quality services that are formative to the needs of the nation of Zimbabwe and the world at large (Nyagura, 2013).

4.1 UZ ICT Infrastructure

The UZ is one of the public institutions of higher learning privileged to have fairly modern ICT infrastructure. One of the key elements of the ICT infrastructure is the data network. The architecture of this data network at Mount Pleasant campus is a star ring. The ring links critical points in the network serving as the backbone with several star networks tapping into this ring. In computer networking terms, this forms a campus network with some quarters referring to it as enterprise network. The network has flexibility built into it through wireless network service which complements the limitations of the wired infrastructure. The recent past saw the institution upgrading its wireless component to an enterprise edition of wireless network covering the greater part of the campus. The university has another smaller remote campus at Parirenyatwa hospital which houses the school of medicine. These two campuses have local data servers which play complementary roles to each other. It is critical to note that the Centre for High Performance Computing (CHPC) is located at the UZ in close proximity to the UZ Computer Centre (the department mandated with handling all ICT related issues of the university). The CHPC houses the super computer for Zimbabwe and this makes it convenient for the university to utilise it where complex analytics and computing is required in as far as IoT implementation and operation is concerned.

4.2 UZ Challenges That IoT Can Solve

An in depth analysis of the UZ case reveals a plethora of challenges that the institution of higher learning is facing which are also some of the major factors affecting the tertiary education sector in general. It is crucial to note that the evolution of technology brought with it more efficient and effective ways of operating in business. These efficient and effective ways can be adopted and implemented by the UZ in as far as human resources are concerned. The institution has a large staff complement and fairly modern human resources system but lacks the ability to technologically monitor the human resources and hence their inability to implement performance based remuneration system (i.e. the number of hours an employee is at work is not accounted for). The institution has also dismissed some employees who were found guilty of imposing ghost workers, a situation that could have been easily averted by integrating the human resources system and the gating system. It is on record that authorities in the institution have on several occasions sent out calls that doors be locked and lights be turned off when rooms are unoccupied and in some instances failed to account for the culprit.

The development of the smart campus should see problems associated with parking and accommodation allocation on campus being a thing of the past. When it comes to transportation, the university lacks a transport system which is technology enabled for both students and staff. In as far as fleet management is concerned, the institution does not have the reliable mechanisms in place to monitor their fleet for both maintenance and transit. Furthermore, technology is evolving the way we teach and learn, hence the need for the institution to modernise the lecture rooms allowing for better course management, collaboration and involvement of students. It is therefore critical for the institution to introduce a modern flexible system of learning and teaching which embraces the use of smart devices and their capabilities in the process of learning and teaching with the core objective of improving the learning experience for students and educators. Last but not least, the institution has a major challenge in controlling access to university resources by both registered and unregistered students as well as the need to modernise building infrastructure for security and ventilation so as to create a safe and habitable environment for both students and members of staff.

5. METHODOLOGY

This research adopts the case study approach. This approach was adopted as it was deemed appropriate with the technology under spotlight as implementation is not homogeneous as it varies from organisation to organisation even within the same industry. A case study allows for triangulation which is critical for in depth understanding of the status quo of a particular entity making it easier to customise solutions (Ridder, 2017). In the case study approach, two major tools were implemented in gathering information relevant to the development of the IoT framework for UZ. The first tool was document analysis to have a better understanding of ICT infrastructure, ICT investment, systems, procedure and the generic make up of UZ. Journal articles, books, websites and other published materials were also consulted to gain knowledge on IoT critical for the development of IoT framework of UZ. The second tool was engaging key personnel of UZ as this procedure complements the weaknesses of organisational document analysis.

6. PROPOSED IOT IMPLEMENTATION AT THE UNIVERSITY OF ZIMBABWE

The world is experiencing rapid technological and economic transformations with far reaching effects. It is therefore critical that business organisations adopt new technologies in order to adapt and become agile thereby enhancing efficiency and effectiveness in their operations. One such technology that UZ can adopt to become more efficient and effective is IoT. The investigation and case analysis process revealed that the UZ has the capacity and capabilities to adopt and implement IoT technologies in order to improve the learning experience and management of its resources. This can be achieved with economically reasonable effort as the institution is endowed with the larger portion of required resources which include ICT infrastructure, systems and expertise. In this regard, this study developed a framework that it is proposing that the UZ and institutions with similar stature in underdeveloped and developing countries can utilise as a guide in the adoption of IoT for the betterment of the tertiary education sector. This framework is a tool that empower institutions of higher learning in leveraging their past, current and future ICT investments through capacitating their ability to fully harness the power embedded in ICTs. Figure 3 illustrates this framework diagrammatically.

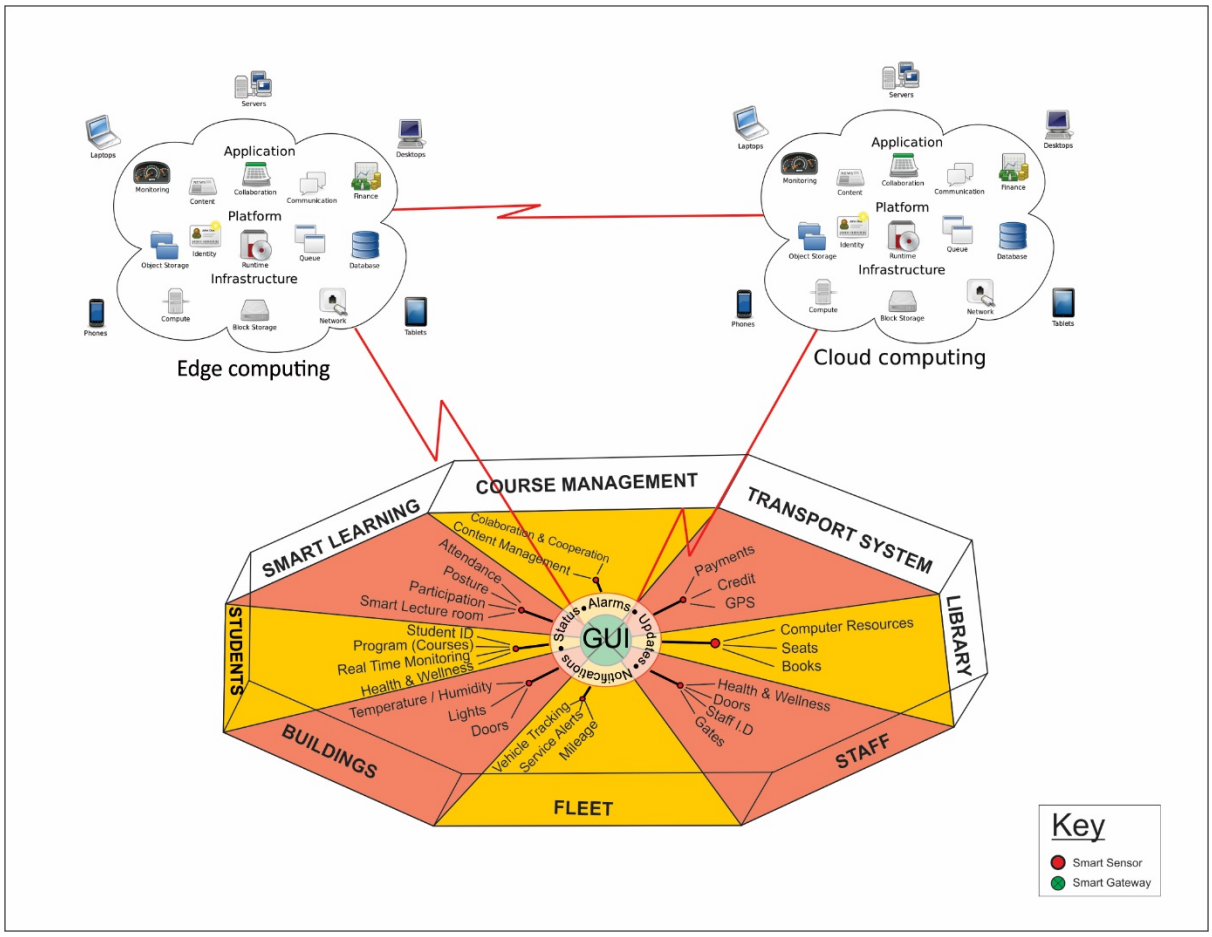

Figure 3: IoT Adoption Framework for University of Zimbabwe

The framework design took cognisance of the physical and virtual structure of the institution as well as other supporting services required to ensure excellence in service delivery. This resulted in at least ten major components being identified from which data can be collected, analysed and used to improve the learning experience and management of resources. These components include buildings, students, smart learning, course management, transport system, library, staff, fleet, edge computing and cloud computing as discussed next.

6.1 Buildings

The institution is endowed with an array of buildings that are used for teaching, administration and technical support. The institution can implement various IoT related technologies for the betterment of activities that are aligned to both its students, workforce and resource utilisation. In this case, it results in the modernisation of HVAC system, lighting system as well as the security system which may require integration with both the HR system and student management system.

6.2 Students

Students are the clients that an institution of learning exists to serve. In the provision of the learning service, institutions should ensure their clients consume the products in a secure and comfortable environment. In this regard, students are associated with various attributes that the institution can take advantage of so as to provide a memorable learning experience. The attributes include their whereabouts, student identification, health and wellness, attendance, participation, program, marks, payments, etc.

6.3 Smart Learning

At the UZ campuses, there are several lecture rooms which serve different programmes in various fields of study. The existence of these diversified programs entail diversity of requirements in as far as requirements for smart learning is concerned. Generally, there is the need to incorporate smart boards, smart devices, projectors, terminals,

network connections, etc., so as to broaden activities in the learning process as well as automating the note taking exercise. This should go a long way in supporting university stakeholders with disabilities.

6.4 Course Management

Courses are critical in the learning process as they are the building blocks of programmes that students enrol to study at an institution. Programmes under study have evolved to incorporate courses from various fields hence the need to have a management system that is accurate and broad in perspective. In some instances, there is the need of collaborative efforts from individuals in the same department, different departments, and different institution or even with industry.

6.5 Transport System

The existence of a campus of higher learning requires a predictable and reliable transport system that ensures accessibility of the campus at all times. As the government is advocating for mass transportation, it is therefore key for the institution to incorporate that effort into their systems and portal as this helps with the next available transportation to and from the campus in real time including the fares.

6.6 Library

One of the key resources in the process of learning is the library system. The current library system needs upgrading so that it is integrated with students and HR systems in order to have an automated access management process. It should further allow for user to check in real time availability of seats and other resources such as books and computers.

6.7 Staff

It is important for any business organisation to pay for work that has been done. This is based on the fact that business organisations exist for the minimisation of costs whilst maximising the value of stakeholders. One of such costs is accrued from the services that are offered by the HRs. In this regard, it is critical to ensure that the contribution of each employee in hours' terms as well as their whereabouts on the campus and off-campus be accounted for during working hours. In other words, our institutions should be able to implement performance based remuneration system thereby ensuring financial efficiency.

6.8 Fleet

The UZ has a fleet of vehicles which are used to support the day-to-day running of the institution. This fleet requires close monitoring when in transit to ensure that they are being utilised for activities beneficial to the institution. It is also of paramount importance that a proper track schedule for their maintenance is adhered to.

6.9 Edge Computing

The advancement of IoT technology and the achievements of cloud computing has advocated for a new paradigm of computing, that is edge computing. This is a computing technology based on the school of thought that advocates for the processing of data at the periphery of the network. This approach addresses issues regarding response time, life span of battery charge, reduction in cost of bandwidth including information security and protection (Shi, Cao, Zhang, Li , & Xu, 2016). The UZ has servers on its premises that are used to manage resources and processing data locally. These servers are ideal components and with appropriate modifications can easily be utilised for edge computing.

6.10 Cloud Computing

Cloud computing is the act of utilising a system of remote servers facilitated on the Internet for the purposes of storage, management and processing of data instead of resorting to in-house storage and servers. In this regard, the institution needs to solicit cloud services from companies like Telone to complement edge computing services that it will be running. This serves as back-up to edge computing and storage to the cloud can be done off-peak times.

7. IMPLICATIONS OF THE PROPOSED MIGRATION

7.1 Changing Work Roles and Psychological Effects

The implementation of the proposed framework ushers in a new production system that is flexible and will strategically position the organisation to better respond and meet the dynamic demands of its clientele. The establishment of a network of intelligent sensors empowers the organisation to monitor all objects of interest in real time with the privileges of viewing their status and manipulating their attributes as necessitous. It also creates an environment that enables the decentralisation of decision processes allowing self-regulation of recursive systems. This promotes more of human machine collaboration and the interconnection of these systems enhances the interaction and collaboration of the workforce. All these dynamic changes entail a paradigm shift in the job design of the workforce. The shift means that the workforce requirements of the organisation skews more towards educated skilled employees. This may have a negative mental strain and psychological effect on the workforce as they are required to adapt to the new phenomenon (Dombrowski & Wagner, 2014).

7.2 Management and Control

The implementation of the technology should transform the organisation to be more efficient and effective as it would have been empowered to have greater control on its resources such as HR, students, vehicles, energy, etc., thereby availing financial resources which are key for the development of the institution and services that it provides. The management and control of the institution becomes simplified as the status of components can easily be obtained in real time providing for better and well informed decision making.

7.3 Availability and Susceptibility of Key IoT Infrastructure

IoT is a new technology and as new technology it brings with it new security challenges. These security challenges are augmented by the very nature of IoT as it is founded on the theory of connecting "things". The integration of these various things presents enormous opportunities for attackers as they can utilise numerous threat vectors due to the diversified composition of the IoT infrastructure and has an adverse impact on availability. It is crucial to note that system attacks, attackers and attacking tools are evolving at an alarming rate. The system attacks are becoming more complex, executed with greater speed coupled with simplicity and readily available tools hence the attacker needs not to be a sophisticated programmer but rather a mere computer user. It exerts more pressure on the institution as it has other none technical challenges to grapple with. Therefore, the institution must become agile, learn continuously and evolve as the technology evolves ensuring that security is applied on three key layers which are policies and procedures; products and people (Ciampa, 2017).

8. CONCLUSIONS AND RECOMMENDATIONS

Technological advancement is creating vast opportunities that developing countries can take advantage of in order to bridge the gap of development with their counter parts in the first world. These opportunities, when fully utilised, empower business organisations and individuals to leverage ICT investments they make thereby harnessing fully the power embedded in ICTs. This study presents an opportunity that institution of higher learning in Zimbabwe and beyond can take advantage of and become more efficient and effective in their quest to deliver higher quality education.

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Biography / Biographies

Farai Francisco Madyira is an Engineering Instructor at the University of Zimbabwe specializing in Network Engineering. He has earned a Master of Business administration from University of Zimbabwe, Bachelor of Business Management and Information Technology from Catholic University of Zimbabwe, Certificate in Cyber Security and Certificate in Digital forensics both from University of Johannesburg and ITIL Foundation Certificate in IT Service Management. Currently, he is pursing PhD qualification in Engineering Management at the University of Johannesburg. He has also co-authored journal papers. His research interests include cloud computing, digital forensics, cyber security, ICT investments, systems thinking and IoT.

Dr Barend W Botha A senior lecturer at the University of Johannesburg and supervisor for Farai Francisco Madyira