A Strategic Framework for Smart Campus

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Abstract

Smart Campus has emerged as an important concept of embedding technology in education. In recent years, it has gained an enormous amount of attention from professionals, academics, and researchers from multiple disciplines. However, still, the concept has not been developed as a whole and lacks framework. This study, therefore, conducts intensive research to revise the recent accomplishments in the field of smart cities in general and smart campus in particular. The research proposes and defines the underpinning criteria for developing a smart campus and propose a strategic framework for its components. The findings suggested that the framework was based on IoT and cloud computing as the main supporting infrastructure which includes eight main criteria and 25 sub-applications such as: Smart Card or E-Card, Smart Classrooms, Energy Management, Adaptive Learning, Smart Transportation, Security & Safety, Optimization & Analytics Data Center and Smart Facilities Services.

Keywords
Smart Campus, Internet of Things (IoT), Smart Cities, Cloud Computing. Adaptive Learning.

1. Introduction

Current emerging technologies have improved the living standards of individuals and enhance the quality of their lives in many aspects. However, the critical factor in developing societies is a good education, which plays a vital role in building future generations and cultivating the way they think. Therefore, there appears a current need to integrate the recent development in technologies into the existing education institutes. Moreover, with the ongoing need to utilize sustainable resources, merging educational institutes with new technologies is not the only solution. A combination of current technologies with sustainable and environmentally friendly resources together can only act as the catalyst to reshape the present educational institutes by the concept of smart cities in general and smart campus in particular. As (Harrison *et al*., 2010) in the IBM journal of research and development defined smart cities as *"urban areas that exploit operational data, such as that arising from traffic congestion, power consumption statistics, and public safety events, to optimize the operation of city services."* To have a more in-depth view of smart campus; (Villegas et al., 2019) applies the concept of smart cities to define smart campus as an integration of three fundamental axes which includes: Data acquisition using IoT, Data centralization and use of big data for the management and analysis. The integration of axes allows the traditional campuses to be able to effectively manage the information generated within the campuses.

Recently, due to the promising expected results of applying these principles in real life, universities and research ins titutes have focused their studies on smart cities and sustainable development.
Similarly,the United Arab Emirates has recently become an incubator for applications for smart cities aimed at placi ng Dubai or UAE on the map as the world's first smart city (Kumar, 2016). Following the same agenda, American University of Sharjah (AUS), which ranks 376 worldwide and 7th in the Arab region ("Top Universities," 2018) have recently launched focused Doctoral programs on 'Smart Cities Management' and 'Sustainable Construction Management' ("Ph.D. in Engineering," 2018). Therefore, as a part of the recent global focus on smart cities, it became inevitable to facilitate those cities with smart educational facilities, called "The Smart Campus." This research, therefore, intends to present the concept and architecture of 'Smart Campus' with a focus on defining the underpinning

criteria to develop a smart campus, and propose a strategic framework for its components, which would allow the administration to evaluate "How smart is the university campus?".

2. Smart Campus

To understand the concept and infrastructure of smart campus; it is necessary to defined smart cities. (Harrison *et al*., 2010) Proposes that a smart city is dependent on three foundation concepts: *Instrumental, Interconnected, and Intelligent.* Therefore, to convoy with its application and advanced technologies, the smart campus must have the same features of smart cities. Since many application for smart cities needs sophisticated infrastructure; there is a need to search and define the infrastructure on which smart campus can operate. Several studies have proposed Internet of Things (IoT) and Cloud Computing to be the main fundamentals of smart campus. Cloud Computing is merely using the network server on the internet instead of the local server or computer to store and manage data (Griffith, 2016). Moreover, IoT is simply the interconnection via the internet of several computing devices to process and perform daily activities by sending and receiving data on the internet. (Liu *et al.*, 2014) Proposed the overall architecture of the smart campus, where it was divided into three platforms: comprehensive perception network foundation platform based on the internet of things, service support platform based on cloud computing, and intelligent application platform centered on users. He also discussed the concepts of each of platforms, how to manage the cloud network infrastructure and support services, and what elements should comprise these platforms. Moreover, (Chao Huang, 2017) in his study analyzed and compared differences between network in traditional campus and that on smart campus and made proposals on how to build smart campus from the perspectives of cloud computing and internet of things. He showed several advantages of the smart network compared to the traditional network; in terms of resource integration, reduction of capital investment, reduction of energy consumption, improvement of information security, and openness, and sharing. Furthermore, to distinguish between the Digital Campus and the Smart campus, (Xiao Ni. 2013) compares the technical environment, application, and management systems for both digital campus and smart as per figure 1.

	Digital campus	**Smart campus**
Technical environment	Local area network Internet	IOT Cloud computing wireless network mobile terminal RFID
Application	Digital teaching resources Distance education Digital library Administrator of networks	The smart system of sensory ability, interoperability, control capabilities
Management systems	Isolated system	System sharing Intelligent Push

Figure 1. Comparison between Digital and Smart Campus

Figure 1 explains the difference between the infrastructure of a digital and a smart campus. Therefore, it can be concluded that all these previous publications can work as a guideline to create the architecture of smart campuses. Adjacently, all the previously mentioned proposals suggested using IoT, Cloud Computing, and RFID sensors as the primary technology or tools to build the smart campus infrastructure. Thus, these proposals can be considered as a part of the framework for the architecture of smart campus. This research will discuss different criteria and application in the subsequent section.

2.1 IoT Services for Smart Campus

(High, 2019) Defined the Internet of Things (IoT) as a strategic tool that can handle a plethora of data and is considered as one of the top 10 strategic technology trends. It can connect the existing built networks ("The Internet of Things," 2011). As an example, Cisco categorizes IoT applications in digital campus into five main categories (Digitizing Higher Education") Building Control and Management, Security and Access Control, Video and Information System, Location and Attendance Systems, and finally Energy Monitoring and Control. Moreover, Cisco and Deakin University have collaborated to deploy Cisco Mobile Experiences (CMX) to provide cloud learning and location

analytics information (Digitising Higher Education"). This way, it can enrich the learning experience of both faculty and students and provide library usage data to the university (DeakinAir, 2019).

Additionally, the face recognition technology can save up to 2.5 hours a week of teaching time, if it replaces the traditional methods of students' roll call (Lovell, 2019). Nevertheless, it was also estimated that we spend almost three working weeks of the year to authenticate ourselves to several services, whether computers or humans provide them. All this consumed time in proving the identity, resetting passwords, accounts verification, documents' submissions, and waiting in queues can be saved if it is replaced by a smart identification technology (Lovell, 2019).

2.2 Proposed Models for a Connected Campus

Throughout the past few years, many proposals started to appear in the field of digitizing and connecting the educational entities. Similarly, Cisco developed the framework, as shown in Figure 2, to "connect several buildings domains such as lighting and automation under one single IP network" (Shakib, 2016). It was initially developed to support business industries as a part of the digital transformation of companies. But in 2016, Cisco expanded this model to the educational sector as it seemed to be one of the potential future markets in adopting IoT and digital transformation. This framework proposes nine main aspects that can be covered under the IoT applications of smart campus. It includes Energy Management, Bring Your Device/ Mobile Learning, Intelligent Digital Signage, Tele-presence in classrooms, Campus Lighting, Campus Wi-Fi, Building Optimization Analytics, Smart Parking, and Campus Operations Centre (Shakib, 2016). The framework recommends deploying IoT in all these nine aspects as it will result in improving the campus quality and efficiency.

Figure 2. Cisco Connected Campus Proposal

Similarly, CenturyLink has also discussed the IoT services that can transform and digitize the campus. Their model consists of 7 areas that IoT can contribute to change the campus nature from traditional to smart, as shown in Figure 3. These areas are: Energy Management, Fleet Management, Security and Safety, Venue Services, Learning Spaces, Digital Connections, and Data Analytics ("IoT Services that," 2018)

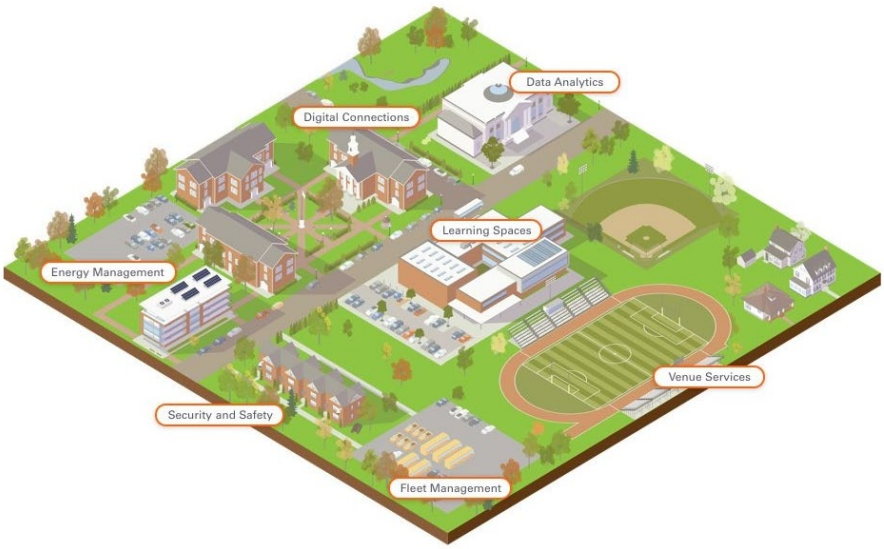


Figure 3. CenturyLink Proposal for IoT services in Future Connected Campus

Therefore, it can be concluded that the term "connected campus" describes the ability to perform a more informed decision-making process by integrating several IT devices and applications with the surrounding environment. Similarly, the report ("Build an Intelligent," 2018) highlights several applications such as smart lighting, video surveillance with analysis, parking, and transportation management, facility access control, interactive signage and kiosks, asset protection, and wayfinding. The main concern in IoT applications is the responsibility of the data collected from students, faculty, and visitors. The methods of data collection have to be transparent and work toward increasing awareness by highlighting the benefits of these applications to all campus users and stakeholders. Finally, the IoT service provider should follow and understand the campus data privacy regulations, along with protecting the students, faculty, workers, and visitors ("Leveraging the Internet," 2018).

2.3 Adaptive Learning

Adaptive learning is a method of education that leverages specific computer algorithms to tailor the educational strategy as per each student's needs. Furthermore, it retargets students with customized educational resources and activities which fit each of their unique needs. (Zeiler and Matthew, 2012) States that the educational material presented to each student adapts and reshapes to fit the students' learning needs as implied by their exam answers, assignments, and classroom experience. While traditional learning continuously faces the limitation of systemized learning experiences, which does not consider differences in learning experiences between students, adaptive learning recategorizes students from passive receptors to active collaborators in the educational system.

Similarly, computerized adaptive testing (CAT) follows the same intuition of adaptive learning and applies it to exam taking. Instead of traditional standard exams for all students, CAT aims at tailoring questions as per the exam taker's needs. (Magis *et al.,* 2017) Clarify that after each answered question, CAT identifies the student's level of understanding of the question, and depending on it the next question is presented to maximize the precision of testing the student. For example, if the student performs well on a question of minimal difficulty, the criteria are updated, and a tougher question will be presented, and vice versa. CAT provides more accurate results for both medium-level score students, and extreme level ones. Whereas adaptive learning frameworks provide four primary services: management of the education process; adaptive learning content and resources; electronic evaluation and testing; and e-services to support traditional score measurement (Arnaudova *et al.,* 2016). The advantages of adaptive learning are promising and are continually evolving and being adopted worldwide. Therefore, it seems essential for adaptive learning to be considered as a supportive tool for learning in future smart campuses.

2.4 Energy Management

Deploying energy management systems inside the buildings results in the reduction of energy costs in the buildings by 11 percent in phase 1, as shown in the case study by ("NCTU Smart Campus", 2017*)*. The cost-saving percentage is expected to reduce more after implementing phases 2 and 3. To sum up, the actual implementation of IoT in energy management inside campuses may result in 11% savings for the costs of energy. Therefore, this is a significant reason to involve and utilize IoT as the main pillar for optimizing energy management inside campuses.

On the other hand, (Ahmed and Kim, 2018) proposes an energy trading system between electric vehicles. They suggested an energy trading system between electric vehicles inside a parking lot. The model proposes a parking lot control center (PLCC) that monitors and controls the energy trading between electric vehicles. It is responsible for optimizing and maximizing profits through selling and buying electrical energy for cars inside the parking lot. It monitors the demands and offers of cars in the parking lots and supplies energy to cars with low energy by buying it from cars with excess. The process involves four layers: the parking energy layer, data acquisition layer, communication network layer, and the market layer. Therefore, it can be concluded that integration of IoT in energy management shows promising results and is a significant criterion for the smart campus framework.

2.5 Enhancing Mobility in Smart Campus

Another significant criterion in the framework of Smart campus is efficient mobility. (Torres-Sospedra *et al.,* 2015) proposes an indoor positioning system that can be developed to support finding way inside Universitat Jaume I (UJI). The paper focuses on enhancing the positioning system inside a supposed to be smart campus in future. Two mobile applications were developed for the study, and students tested both, university staff, and visitors who later on reported the usefulness of both applications in locating the campus facilities and improving the spatial orientation. *SmartUJI APP* as shown in 4 allows users to use the campus map in order to obtain information and navigate several locations of university's facilities. Moreover, the second application *SmartUJI AR,* shown in figure 5 provides an interacting augmented reality map where users can experience navigating the routes of their desired locations, facilities or any other point on campus.

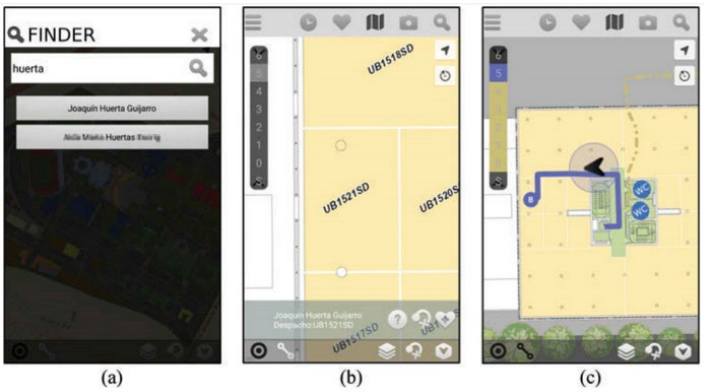
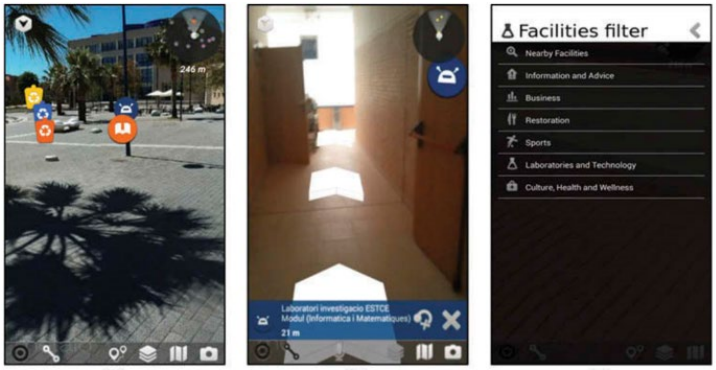


Figure 4. SmartUJI App



(a) (b) (c)

Figure 5. SmartUJI AR App

Therefore, it can be concluded that efficient and effective mobility by using IoT will transform the traditional campus into a smart campus.

2.6 Safety and Security

The report (CenturyLink, 2018) proposes implementing IoT in safety and security of the campuses. IoT can assist the campuses leverage to boost their security in the following manner: Asset protection, Facility access control, and Interactive signage and kiosks. The implementation of I0T can benefit protecting the investment of millions of the universities by putting beacons on the resources of high value, which can be tracked. Similarly, IoT provides the campuses to have control over the buildings, who and when can they be accessed, with a log of entrance and departure to prevent any misfortune. Similarly, IoT can be used to convey pertinent information on the interactive signage and Kiosks in case of any emergency.

Therefore, it can be concluded that integration of IoT in safety and security shows promising results and is a significant criterion for the smart campus framework.

3. Conclusion

To sum up the results, the main underpinning criteria of a smart campus can be summarized in eight main criteria and 25 sub-applications. All these criteria and sub-applications are based on **IoT and cloud computing** as the main supporting infrastructure. Finally, a summary of the designated criteria of smart campus and its applications are gathered and combined in Table 1. It is important to highlight that all these criteria and applications are based on literature review and its relevance to smart campus, then combined in the following table:

Table 1. Underpinning Criteria of Smart Campus

Criteria	Applications	Reason
Smart Card or E-Card	- For Attendance (Classrooms, Labs, access to facilities, etc...) - Dorms (All residential activities and administration) - For Library usage (booking, borrowing, registration, printing, etc...0) - E-Wallet (Payments and verification with E-invoice for: Registrar, administration, cashier, restaurants, financial holds, fees, etc...) - To Record all Personal Data (Student Information, admission, transcript, graduation information, student records and activities, etc...)	- Quick identification for all transactions, and a personal database. Accessible through cloud.
Smart Classrooms	- Virtual Reality (For Labs, experiments, Site Visits, Simulations, etc...)	- Enhance the learning quality, more interactive, more

	- Remote Digital Learning (Online Lectures, Visual interviews, Cloud Storage, online access to all course information and lectures, etc..) - Interactive Cloud Sharing platform (between classmates & professors, between the Market and the University, between Government and University, etc...) - Collaborative Research (connectivity and communication with several universities, companies, governments for research)	collaborative, time efficient, user-friendly, and sustainable.
Energy Management	- Buildings Energy Management System (Monitoring and Automated: Heat & Air Conditioning, Lights, Power Devices) - Sustainable Energy (Solar Power, Sustainable design Buildings) - Smart Street Lights - House Management System (for residential end users usage) - Energy Trading System (for Electric Vehicles inside parking)	- Better utilization of resources, less cost, more sustainable, monitored and controlled, more data to analyze, better planning.
Adaptive Learning	- Adaptive Learning (Customized Learning according to market needs & students' interests, Customized Learning for Students' Weak-points) - Optional Supplementary Courses in specialized fields (Beside Curriculum) - Computerized adaptive testing (CAT) - (Tailored questions as per exam taker's needs, questions depend on previous answers for more accurate results, Deep assessment).	- Customized, improve weakness points for students, more visibility to class performance, accurate testing, supports the student and gives recommendations, optional extra courses, etc…
Smart Transportation	- Smart Parking - Fleet Tracking of all Campus Transportation (for Logistics, Transportation, Smart Bus Shelters, etc...) - Intelligent Signage (for Navigation, Broadcasting, etc...) - In-Campus Navigation (Smart Kiosks, Way-Finding for Offices, Room, Facilities, Events, etc...)	- Optimized logistics, Informative, quick notifications, better mobility.
Security & Safety	- Smart Safety & Security Systems (Tracking, Surveillance, Evacuation, etc...)	- Protective in advance, root cause analysis, more data.
Optimization & Analytics Data Center	- Operations Optimization - Data Storage - Research Center	- Up to date enhancements, Data lakes, Data openness and classification.
Smart Facilities Services	- Sports Fields and Students' Centers/Libraries/Restaurants. - Facility Management Smart System. - Campus Social Network (Events, Broadcasting, Accessible information.	- Interactive campus life, responsive buildings, quick.

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