C-BRIG: A Network Architecture for Real-Time Information Exchange in Smart and Connected Campuses

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Abstract—**Education at all levels is one of the major driver of sustainable development in any nation. The number of institutions of higher learning and enrollment in Africa has continued to increase significantly over the last few years. However, the needs of the knowledge society is still yet to be met due to challenges of overcrowding, infrastructure deficiencies, and inadequate access to international knowledge. In this paper, we developed a robust network architecture that enables real-time information exchange within and among connected campuses using connections of local networks and mobile applications. Campus Bridge Information Grid (C-BRIG) is a novel initiative that meets the information and social needs of staff, faculty, and students of tertiary institutions in developing nations. The expanded version of C-BRIG named i-Spider Information Grid (i-SPIG), will facilitate real-time information exchange among university campuses that are already on the C-BRIG platform. The proposed framework will help in boosting the productivity of every member of the university community, and foster research collaborations and social interactions among several institutions that are physical separated but digitally connected.**

Index Terms— **smart campus, e-learning, ICT, sustainable education**

I. INTRODUCTION

INSTITUTIONS of higher learning has a critical role to play in the realization of a sustainable development in any nation, most especially developing countries. This fact has been formally established at different fora including the Agenda 21 of the 1992 United Nations Conference on Environment and Development [1], the 2nd World Summit on Sustainable Development in Johannesburg in 2002, and the United Nations Decade of Education for Sustainable Development [2]. Education helps in linking sustainable development goals and targets to local realities [3]. In recent time, trade, foreign investment, and technology transfer are becoming increasingly significant to national development [4]. So far, one of the most favourable terms of engagement with the global economy in the pursuit of globalization is education [4]. In a bid to ensuring that university policies

align with sustainable development goals, more than 600 universities across the world have signed international agreements and conventions to prove their commitments [5]. In this way, education and skill acquisition are central to the process of development.

Although the number of institutions of higher learning and enrollment in Africa has continued to increase significantly, the needs of the knowledge society is still yet to be met due to a limited coverage of university education [6]. Available universities are faced with serious challenges of overcrowding, infrastructure deficiencies, and inadequate access to international knowledge. These factors are largely responsible for the deterioration that hampers the quality of scholarship among faculty, staff, and students. Among other things, the problem of communication access has been identified for urgent attention. Both intra-communication and inter-communication among institutions of higher learning in Nigeria are done through traditional means which are usually inefficient.

Seamless and effective communication of useful information will enhance administrative flow, boost academic and research productivity, and stimulate social interactions within and outside the university community. Universities in Africa can leverage existing modern Information and Communication Technologies (ICTs) to provide interactive learning, uninterrupted audio and video transmission, and recording and uploading of lectures and achieve smart education [7]. High proliferation of smart devices and advances in mobile communication technology make electronic learning (e-learning) and mobile learning (m-learning) suitable for virtual classrooms and virtual meetings in a university environment [8]. This technology can equally be adapted for administrative functions to facilitate timeliness, transparency, accountability, and reliability.

Although several frameworks for learning environment exist [9-12], they do not adequately considered the peculiar nature of the operating environments in developing countries. Emerging economies are plagued with quite a number of extreme factors which include highly unreliable power grid networks, and pure mobile networks built without existing wired networks.

In this paper, we developed a robust network architecture that enables real-time information exchange within and among connected campuses using connections of local networks and mobile applications. Campus Bridge

Information Grid (C-BRIG) is a novel initiative that meets the information and social needs of staff, faculty, and students of tertiary institutions in developing nations. This will help in boosting the productivity of every member of the university community, and foster research collaborations and social interactions among several institutions that are physical separated but digitally connected. The expanded version of C-BRIG named i-Spider Information Grid (i-SPIG), will facilitate real-time information exchange among university campuses that are already on the C-BRIG platform.

The remaining parts of the paper is organized as follows: Section II presents the C-BRIG architecture, the key component technologies, and their functionalities; Section III explains the operation of the expanded version of C-BRIG, i-SPIG, for smart and connected campuses; Section IV highlights the major contributions of the proposed network architecture, with emphasis on its adaptability to the context of developing countries. Section V gives a brief summary of the paper.

II. CAMPUS BRIDGE INFORMATION GRID (C-BRIG)

C-BRIG is a communication network architecture that facilitates digital transformation of academic, research, administrative, and social events and activities with the use of mobile applications. The mobile application has a number of general features which are accessible to all users. However, some features are restricted to certain category of users as related to the classes of people in a university community.

Audio and video capabilities are built into the system to enable voice and video calls where and when necessary. With these, users can leverage on either on both capabilities to enrich their horizontal and vertical communications beyond the traditional means of information exchange. In addition, the C-BRIG mobile application allows the exchange of text documents and media files. Users can conveniently share files of common extension types and that of specialized format such as '.sav' and '.dta'. The two features mentioned above are constituents of the generic class of users.

The specific features include virtual Dashboard (vD), virtual Conference Room (vCR), virtual Library (vL), virtual Personal Wallet (vPW), virtual Staff Room (vS), virtual Lecture Theatre (vLT), and virtual Hangout Spot (vHS). The vD facilitates seamless dissemination of information from the university management to all faculty, staff and students in real-time. With this feature, top management staff, the office of the registrar, administrative officers, and faculty heads can easily reach the entire faculty, staff and students from the convenience of their offices, at any given time/day of the week. The vCR is a virtual room where faculty and staff across colleges confer with the aid of several audio-visual tools. This feature ensures that real-time conference sessions can hold irrespective of physical distance barriers. The vL is designed as an electronic replica of the traditional university library. Besides all the services accessible in the physical library, the vL comes with the extra benefits of 24-hour accessibility, real-time access to "Help" features,

collaborative study platforms, and so on. Access is granted based on the university policy and regulation.

Furthermore, the vPW can be regarded as a personal account for faculty, staff and students where personal effects and correspondences can be domiciled. Through the vPW, personal effects such as test scores, results and scripts, fee payment status etc. can be viewed. The vS is an electronic replica of the physical staff room. It allows lecturers within and outside various departments and colleges to engage in discussions at the convenience of their respective physical location within the university premises. It is most useful for "on-the-go" collaboration irrespective of space and time. It is worthy of note that accessibility is granted to academic staff only. Using the vLT, lecturers and students can interface on an electronic platform in lieu of physical classroom lectures as shown in Figure 6. Here, emergency/makeshift classes can be held at any time of the day. Accessibility is granted to only lecturers/students of a given course of study. The vHS is primarily designed to be a hub where students can socialize at will. Here, users can create custom groups to suite their preferences. This feature is accessible to all students.
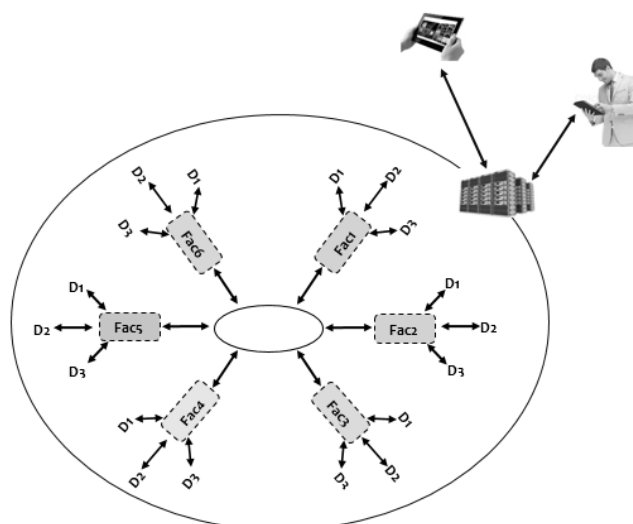

Figure 1: Conceptual Framework of C-BRIG

This system is designed with more considerations for efficiency, simplicity, and flexibility. Users are required to be pre-registered for access to institution's server. A personalized authentication detail (user ID and password) is generated for each user. The default password can be changed at will. As shown in Figure 1, users require the C-BRIG platform for information exchange from FAC1 to FAC2 within the same university. The user at FAC1 logs on to C-BRIG mobile application installed on a personal computer or smart device. The application prompts the user to enter the personal authentication details. Entry of a valid user ID and a correct password will immediately grant access to the C-BRIG platform with the homepage on display. The C-BRIG home page shows a comprehensive directory of all colleges and departments registered on the mobile platform.

Upon accessing the C-BRIG platform, the user has a choice of either private correspondence/contact with another user (whose identity is known) in another institution, or access any of the "Convergence Points" of choice.

Convergence Points (CPs) are virtual meeting areas where users can meet to interact or correspond at any given time of the day. This also doubles as a unique feature of the C-BRIG. The main CPs hosted on the C-BRIG are vCR, vL, vPW, vS, vLT, and vHS. User can contact colleagues from other colleges or departments by accessing the CPs. The user simply accesses the CP of choice by clicking on its icon, and thereby engage other users as desired. User can exit CPs by clicking on the "Exit" button when desired. On the other hand, contact can be made on a one-on-one or private basis by using the embedded Instant Messenger software application. Private correspondence is initiated by typing in the User ID of the individual of choice. For example, to contact an individual with user ID 0201KENNETH, the User types in the user ID of the individual and sends the message.
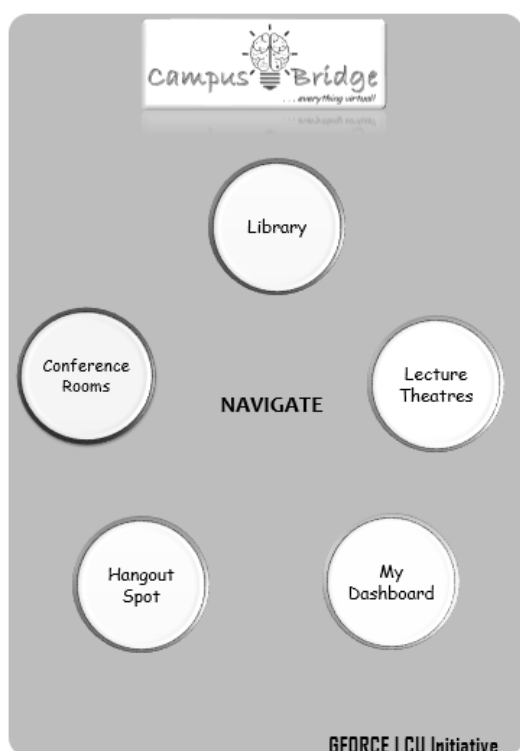

Figure 2: Mobile Application Dashboard

III. I-Spider Information Grid (I-Spig)

The viability of the C-BRIG system as an electronic platform for real-time information exchange within tertiary institutions places an inherent need to explore the possibility of a similar platform with an expanded capacity and capability to facilitate for information exchange between tertiary institutions of learning in Nigeria. This concept will birth the first use case of 'Smart and Connected Campuses' in Africa. The i-SPIG is an electronic hub that facilitates real-time information exchange among univeriory campuses that are already on the C-BRIG platform. It provides specialized access for real-time correspondence and collaboration between management staff, colleges, and departments of different universities simultaneously. This feat is achieved through the i-SPIG which runs on a Virtual Private Network (VPN) setting.

The i-SPIG application, which uniquely connects different the universities, consists of several features that foster correspondence and information exchange at ease. The i-SPIG shares similar features with the C-BRIG platform. However, there are other unique features that are functional within the i-SPIG. A unique perspective from which to utilize the vCR feature is to host (if so desired) joint or emergency senate sessions, and/or become a rendezvous point for Vice Chancellors and faculty heads. Moreso, the vLTs would provide platform for exchange programs for lecturers and students of several institutions.

Leveraging on existing protocols of the C-BRIG system, users across different tertiary institutions can seamlessly correspond or exchange information via the i-SPIG by accessing the secured "Gateway" of their respective institution's C-BRIG. In order to facilitate an exchange from FAC1 of University-A to FAC1 of University-B as shown in Figure 2, the user at University-A logs on to the C-BRIG mobile application and accesses the i-SPIG network by clicking on the i-SPIG icon. This prompts the user to provide an i-SPIG access code for University-A. Entry of a valid i-SPIG password in the login page will immediately launch the i-SPIG network which displays the i-SPIG homepage showing a comprehensive directory of all institutions on the i-SPIG network, and the existing "Convergence Points". Here, LED indicators will notify the user which institution is currently active on the i-SPIG network.

Upon accessing the i-SPIG network, the user is given the option of either having private correspondence or contact with another user (whose identity is known) in another institution, or access any of the "Convergence Points" of choice. A user can make contact with users from other institutions by accessing the CPs. As with the C-BRIG network, the user simply accesses the CP of choice by clicking on its icon, and thereby engage other users as desired. The user can exit CPs by clicking on the "Exit" button when desired. On the other hand, contacts can be made on a one-on-one basis with a user (oftentimes happens between users who are familiar with themselves) in another institution. Users can initiate contact by clicking on University-B's icon to access its gateway, and ultimately the desired contact i.e. FAC1, as shown in Figure 3.
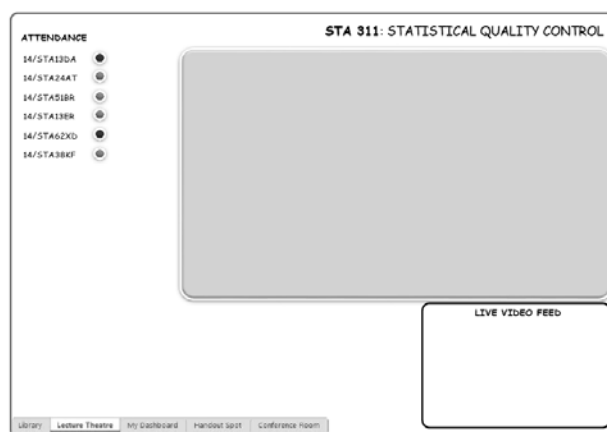

Figure 3: User Interactive Page

IV. CONTRIBUTIONS

One of the major contribution of C-BRIG to smart and connected campuses is the guaranteed network flow. The system does not depend on the internet services provided by the telecommunication sectors and the Internet Service Providers (ISPs). In essence, there is a guaranteed flow of information from one terminal point to another within the campus community. Also, the system offers limited security risk since it is designed to guard against unauthorized intrusion/access. As such, every user (be it staff, faculty, or student) is assured of a high measure of security and utmost privacy of their information exchange. In addition, the C-BRIG platform guarantees convenience of information exchange. The system equally allows information exchange on a consistent basis. Users can enjoy real-time access as long as is desired. More so, C-BRIG is designed to be user-friendly and easy to use. Familiar technology such as file transfer, video/audio communication, instant messaging etc. are utilized and engrained in the framework. Hence, little or no technical skill is required in order to access or use the c-Bridge system.

Specifically, convenience, ease of use, and reliable access, are the prime advantages of the i-SPIG. Since the system runs on a Virtual Private Network (VPN) - via the internet – there exists the likelihood of exposure to malware threats, and dependence on Internet Service Providers (ISPs). To curb this, each institution's cBRIG is only accessible externally through a heavily secured and protected Gateway. As such, every of such external access will be properly authenticated before given access is granted.

V. CONCLUSION

The synergistic alignment of the C-BRIG and i-SPIG platforms possesses a great potential to boost efficiency and productivity within and among smart and connected campuses. By this, institutions could expose their teeming students and lecturers to best international practices, thereby giving them a place to compete on a global scale. This synergy leverages on already existing Information and Communication Technology (ICT) platforms such as server gateways, routers, and access points of the host institutions.

Moreover, the C-BRIG and i-SPIG platforms are notably unique to suit the modus operandi of tertiary institutions mainly due to unique and relevant features, notably the Convergence Points (CPs), which are amongst the pivotal drivers of these platforms.

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