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Design and Deployment of a Mobile Learning Cloud Network to Facilitate Open Educational Resources for Asynchronous Learning

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Abstract: This paper describes the design and deployment of a mobile cloud network that facilitates open educational resource content distribution. The setup utilized clustered single board computers as content, communication and monitoring servers. It was installed in a Public High School where stakeholders, using their mobile devices, were given access to preloaded content via wireless local area network. Initial tests of the mobile cloud showed good network performance. Teachers were randomly selected to evaluate the content validity and delivery of the OER content. Results show that the quality of the network's OER content is very satisfactory. This implementation shows the advantage of mobile cloud computing in the delivery of learning content in remote learning modalities.

Keywords: Mobile learning, open educational resources, remote learning, mobile cloud computing

1. Introduction

The COVID-19 pandemic changed the educational landscape as educators find new and effective ways to reach millions of students worldwide. Educators are forced to employ technologies and strategies to slowly replace traditional face-to-face learning with blended learning methods to narrow the achievement gap (Burgess & Sievertsen, 2020; IAU, 2020; Terada, 2020). Though it had been persisting for some time, this revolution challenges educational institutions in terms of their readiness, technological resources, and human resources.

The digital divide had become more apparent as the pandemic had spread around the world. Equal access to the internet has been a significant issue in the Philippines. Aside from the slowest internet in South East Asia, 45% of Filipinos and 74% of public schools do not have access to the internet. Only about 40% of the country's public high schools have computers with internet connectivity potential. However, only 40% of these schools give students access to and training on using the internet (Jones, 2019). The pandemic challenged the Philippine educational system to evolve to become digital, which most learners are not prepared for (Alipio, 2020).

As a response to this, the Department of Education explored the use of Open Educational Resources (OER). Several countries have already adopted OERs broader use, indicating that this is a future learning solution. Moreover, there is now a growing research interest in maximizing the use of OER's in the current and "post-COVID" education. OERs show promise because of flexibility, cost-effectiveness, and a wide array of applications (Huang, Tlili, Chang, Zhang, Nascimbeni & Burgos, 2020). Since OERs are increasingly adaptable, educators can tweak its substance to fit students' adapting needs and objectives. Instructors can reuse, create, collaborate, and contextualize materials providing wide assortment of materials.

Although OERs are cost-efficient, dissemination of this resource is still a significant challenge. Recent technology developed by the Ateneo Innovation Center (AIC) that focused on Mobile Cloud Computing to cope with high cost, low performing internet access (dela Cruz, Libatique & Tangonan, 2019; Mercado, 2020; Mamaradlo, 2020). Using this technology, students and teachers can access preloaded content in a mesh server that can be accessed through various devices without using the internet. This model has its potential in teaching and learning as it addresses the limited bandwidth and connectivity issues among learners. With preloaded content, the system works as a repository of materials such as videos and documents that can be readily accessed using mobile devices.

This paper describes the design of an offline network to access preloaded open educational content in a mobile cloud network system. The mobile network was deployed in a public high school that aimed to provide offline access to open educational content in the context of asynchronous remote learning modality. This paper also presents the teachers and students perceived quality and mobile learning acceptance.

2. Mobile Cloud Computing

Mobile Cloud Computing (MCC) or mobile cloud technology is an architecture where both data storage and processing take place outside a mobile device. This is based on a new paradigm for the application of mobile where computing occurs in a cloud and that is accessed through wireless connections (Dinh, Lee, Niyato & Wang, 2013). As applied to educational context mobile learning (M-learning) is differentiated from electronic learning (e-learning) and distance learning (D-learning). Rimale, Benlahmar, Tragha & El Guemmat (2016) stressed that students can benefit from M-learning that it facilitates learner interaction, mobile devices are easy to accommodate, mobile devices can be used anytime, more student engagement, mobility and cost effectivity of the devices.

There have been various applications of mobile cloud computing. Most of these applications are internet based or rely on online access for optimization. However, with limited bandwidth to deliver learning content this paper inclines the use of Near Cloud technology. One of the prominent features of the Near Cloud technology is the configuration capability for services such as proxy servers, caching server, database, torrent managers, and communication services which allows optimization of any bandwidth available (dela Cruz, 2018). The nodes of the Near Cloud system are low cost, low power, and low maintenance and can serve as a gateway to the internet. Its architecture has a caching system with terabytes worth of storage which serves as an easily deployable, efficient, and resilient network capable of collecting and transmitting data (Mercado, 2020). A recent study by Talusan, Nakamura, Mizumoto & Yasumoto (2018), demonstrated the implementation of the near cloud architecture for Rural Area Connectivity and Data Processing.

3. Open Educational Resources Adoption

Recently, there is an increase in the literature that referenced Open Educational Practices (OEP) and open resources. Koseglu & Bozkurt (2018), noted that between 2007 to 2017 there is an increase in the trend of peer-reviewed publications that focused on growing awareness of the importance of adopting open practices. This also includes how OERs affect the learning process and teaching practices situated in available courses and platforms with open-source technologies.

Luo, Hosttetler, Freeman & Stefaniak (2020), mentioned that publications about OER include the perception and efficacy of open resources and what hinders the adoption of such. The study stressed that, in terms of quality, OERs are mostly perceived as equivalent to traditional resources and do not harm learning outcomes. Publications, in general, are adept in OER adoption yet studies on barriers in implementation and/or efficacy of these materials are not fully explored.

As practitioners gradually become more accustomed to using OERs, practice about its use is also changing. Adam (2020), stated that as open education is practiced and understood, its implementation is based on the practitioner's "history, worldview, subjectivities, mannerisms, and character" (p.181). This put OER educators in a critical role in the dynamics of the learning environment. Teachers should be viewed as competent in both face-to-face and online instruction and should be literate and skilled users of open resources (Atenas, Haveman & Priego, 2014).

4. Mobile Network Design

The mobile cloud network architecture in this study was designed to be portable, low power and low cost yet capable of the necessary processing capabilities for its implementation. For this, 3 units of Raspberry Pi 3B+ were utilized as servers. It was selected primarily due to its adherence to the network architecture's use case design. It is a low cost, low power and portable Single Board Computer (SBC) and has ample processing power for the network design. Each unit has 1Gb LPDDR2 SDRAM, Gigabit Ethernet port and 2.4GHz and 5GHz 802.11b/g/n/ac Wi-Fi. The Raspberry Pi SBCs were arranged as a cluster to distribute the tasks into three available servers.

The network was designed to host high capacity processing and multiple devices can connect to it at the same time. For this, the Raspberry Pi servers were connected to the network using a D-Link AC2100 Wi-Fi Gigabit router that can provide high bandwidth (up to 300 Mbps for 2.4 GHz and 1733 Mbps for 5GHz). To extend the range covered by the network, Google Wi-Fi Mesh AC1200 (1200 Mbps throughput over 2.4 and 5 GHz) was used. The network design utilized three of these devices for a stable and wireless mesh network.

To facilitate open educational materials and other related resources, each server was installed with open-source software to allow content distribution, communication and network monitoring. The first server was dedicated for content distribution and learning resource management. One of the open resource software installed was Kolibri. Kolibri (2020) is an open-source application that creates an offline server to deliver curated educational resources. It is designed for offline use that packages learning that reduces megabytes worth of data while retaining the original quality. It could be treated as a standalone Learning Management System that features a customizable digital OER curriculum with tools such as exam creation, exercises and differentiated assignment content. It is not necessary for this application to be connected to the internet regularly since updates and latest contents can be synced and shared once it connects with another Kolibri installed device with updated software connected in the same network. Kiwix was also installed in the system. It is an offline content reader for Wikipedia, Project Gutenberg or TED Talks. For this study, an offline Wikipedia was utilized. To facilitate videos and other related media content, the content server was installed with an offline PLEX application. It is a digital media player that facilitates offline access to preloaded music, videos and pictures on a server. Finally, we optimized the server as a collaborative cloud storage with Nextcloud. With this open-source software, the server could facilitate file sharing in an offline local area network.

To facilitate communication among stakeholders within the network, we optimized the second server for real time messaging in case of synchronous learning modality. Rocket.chat was utilized as chat server. This application facilitates collaboration among users thru creating chat rooms for instant messaging and file sharing. The second server was also optimized as a Real-Time Messaging Protocol (RTMP) server. It was incorporated with the network in cases where the server was used as a streaming server and can then be used to stream from multiple sources such as LAN cameras. Since high network traffic is expected in the mobile cloud network, Nginx, as load balancer, uses asynchronous, event-driven web requests. For network monitoring, one of the Raspberry Pi Servers was installed with Nagios Enterprise Monitoring Server (NEMS). NEMS is a pre-configured easy to deploy Nagios Core monitoring software designed to run on microcomputers.

The mobile cloud network was deployed in Kaong National High School in Silang, Cavite, Philippines. As seen in Figure 1, the servers have a wired connection to the gigabit router that can support 2.4Ghz and 5Ghz bandwidth simultaneously. Wi-Fi mesh devices were used to extend the network range. The design utilized three Wi-Fi mesh devices, one of which has wired connection to the router while the rest supported a wireless mesh network. The network is designed to be easily deployable in areas such as school grounds or community centers where students are expected to receive and submit printed learning modules. In these areas, physical distancing and other COVID-19 related protocols are enforced. With the deployment of the network, students are expected to access the materials anytime within a wider range.

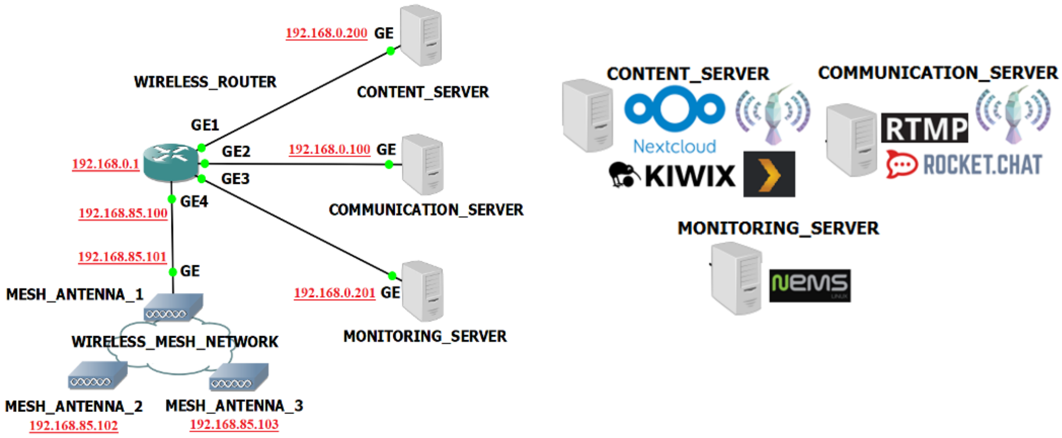

Figure 1. Mobile Network Diagram and Server Design.

5. Characterization of the Mobile Network

5.1 Content Delivery and Management

To facilitate the deployment of the network, teachers and the school administrators were given a demonstration of the network capabilities. Printed manuals were also distributed to the students and parents as well as establishing a social media group for receiving inquiries. It was proposed that during printed module distribution, the students and parents could connect to the network and interact with the supplementary materials. Through the network, they can view and download the supplementary learning resources.

The network was designed to facilitate supplementary materials to the target learners. Following the policy guidelines of the Department of Education, digital file sharing of the modules should only be done by authorized personnel only. Hence, the deployment of the content of mobile cloud network was focused on the distribution and access of supplementary open educational resources. Supplementary materials such as videos, eBooks, simulations and practice assessments were aligned to the Most Essential Learning Competencies (MELC) provided by the Department of Education. Out of the eight subjects in the secondary education curriculum, English, Mathematics, Science and Social Studies supplementary materials were prioritized due to the availability of the resources in the OER repositories.

To be able to connect to the network a client could either connect to the router or the mesh Wi-Fi using any Android, IOS, PC, Linux or Mac devices . The network offers both 2.4 GHz or 5 GHz Wi-Fi bandwidth simultaneously. Once connected, the client can run the applications via opening a browser and typing the IP address of the server that will direct to a landing page of which the user can choose which application to launch in the next tab.

5.2 Network Performance

The initial performance of the network was measured in terms of capacity throughput, network speed and receive signal strength. Four key sampling areas within the school grounds were identified. Figure 2 shows the designated module distribution and waiting areas of which students and parents can connect to the network following the COVID-19 physical distancing protocols. For the first test, capacity throughput was measured for the 2.4 and 5 GHz connection of the mobile cloud network for sixty (60) seconds. Stream tests were done from five (5) to thirty (30) devices. The mobile cloud performs consistently on the 5 GHz compared to the 2.4 GHz band. It was also evident that, in both bands, capacity throughput decreases as more devices are added to the network. However, even at the most number of devices connected that network still showed good throughput performance with 2.52 Mbps on the 2.4 GHz band and 3.15 Mbps on the 5GHz band.

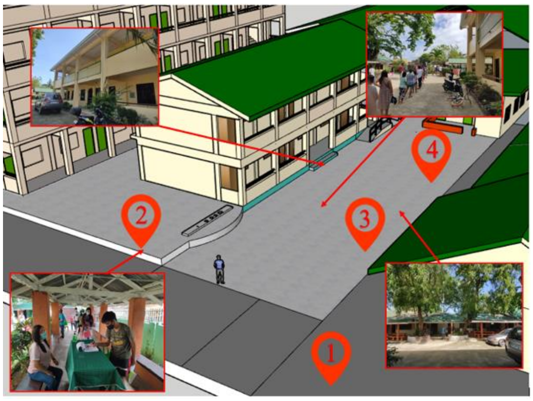

Figure 2. School Site Map, Access Points Location and Module Distribution Area.

The next test measures the bandwidth of the network. Bandwidth was sampled in key areas in the network range and ran for sixty (60) seconds. As seen in Figure 3, comparison of network speeds in the 4 key locations showed high variability. Network speeds vary from 8 Mbps to 43 Mbps with location 3 having the least throughput in the 2.4 GHz and location 2 in the 5 GHz band. Variations in the throughput are possibly caused by adjacent channel interferences of which the current study did not capture. Network bandwidth in the 5Ghz band showed a consistent output. One limitation of the mobile cloud network would be the client's device capacity. Accessing large amounts of data in the network would require a stable and faster network performance that could be limited by the device of the user.

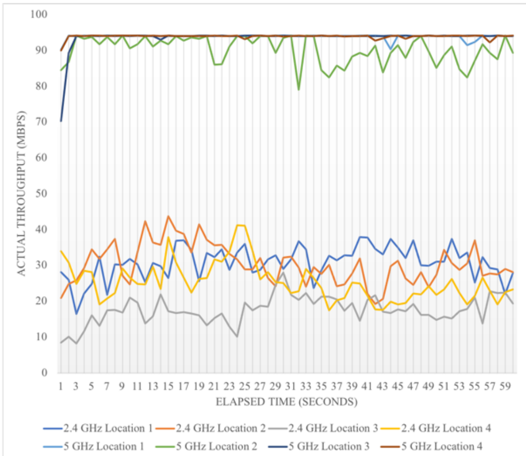

Figure 3. Comparison of Network Speeds of the Four Access Points at 2.4 and 5 GHz.

7. Conclusion

Access to educational resources in times when face-to-face learning modalities are limited puts struggling learners on a disadvantage. The availability of competent learning resources should be made available to all learners despite financial and technological difficulties. This study deployed a platform for the distribution of educational resources that can be locally accessed within the learners' community. The mobile cloud architecture in a mesh network offers a low-cost, low technology requirement, easily deployable and wide range of compatibility systems for the distribution of open educational resources. The system consists mainly of low-cost, low-power consumption and readily available single board computers installed with open source applications for curating and creating learning content. Initial performance tests show that the network architecture is efficient in data transfer and accommodating synchronized usage. It was also evaluated that the network deployed was as more than adequate in the delivery and management of the supplementary learning materials. With the concurrent data provided in this study, future developments on the optimization of the deployed network can enable wider coverage and improved content distribution.

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