

Cost-Effective Mobile Based Learning Content Delivery in Resources and Network Constrained Environments

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Abstract--The advancement in Information and Communication Technologies (ICTs) has brought opportunities for new ways of learning in Higher Learning Institutions (HLIs) through e-learning systems. While these opportunities exist, e-learning contents delivery and accessibility in third world countries like Tanzania is still a challenge due to resource and network constrained environments. The challenges include: high cost of bandwidth connection and usage; high dependency on the Internet; limited mobility and portability features; inaccessibility during offline period and shortage of ICT facilities. So there is a need for a technology to bridge these gaps. This paper explores the opportunities brought by mobile technologies to find out a cost-effective solution for e-learning content delivery and accessibility in HLIs of Tanzania. Specifically, the paper proposes a Cost-effective Mobile Based Learning Content Delivery approach for resource and network constrained environments. The proposed solution has the potential to reduce the cost of bandwidth usage, and cut down server's workload and Internet usage overhead by synchronizing contents from a remote server to a local database in the user's device for offline use. It will also improve the quality of experience and participation of learners as well as facilitate mobility and portability in learning activities.

Index Terms: content delivery; mobile; cost-effective; constrained environment; synchronization and caching policy.

I. BACKGROUND INFORMATION

Higher learning institutions (HLIs) require a cost-effective and efficient system for delivery and accessibility of learning contents which favor personalized and innovative learning while minimizing the development and operation cost. However it has been reported that, persistent internet connectivity in third world countries is still a major challenge for both public and private HLIs [1].

There are existing Learning Management Systems (LMS), like Moodle, which are adopted by the majority of HLIs in developing countries. Moodle is an Internet based LMS which highly depends on the Internet [2]. Despite the great opportunity brought about by Moodle and other LMSs; learning content delivery and accessibility is still a challenge in third world countries due to resource and network constrained environments. Several studies [1, 3, 4, 5, 6] have reported that the main challenges facing existing e-learning systems include: high cost of bandwidth connection and usage; the need for continuous internet connection; limited mobility and portability features; un-accessibility of e-learning contents during offline

period; Internet usage overhead; high cost of purchasing hardware and shortage of ICT facilities. Therefore, there is a need for a technology to bridge the gap. Adaptation of mobile technologies is growing at a rapid pace bringing along a lot of opportunities that can enhance contents delivery and accessibility for HLIs within resource and network constrained environments. During survey it was found that majority of HLIs in Tanzania own basic ICT infrastructures such as Local Area Network (LAN), Internet, computers, and mobile technology that form the basis for the establishment of e-learning. Furthermore, it was found that 85% of students own laptops, 65% own smartphones and 78% own mobile phones. This means that majority of students own more than one mobile device which is an opportunity to be used as a vehicle to facilitate access to learning contents. This study explores opportunities brought by mobile technologies to find out a cost-effective solution for e-learning content delivery and accessibility for HLIs in resource constrained environments.

Previous studies [7, 8] proposed Mobile Moodle (momo) and Mobile Learning Engine (MLE). Both applications are based on J2ME, while the MLE project developed a client application and an additional web version to access Moodle courses from mobile browsers. Sakharkar [9] argued that the structure of XML schema used in MLE caused problems such as high memory requirement and delay in response time. Jordi [10] proposed Moodbile; the android application that supports both online and offline accessibility by storing offline contents in memory cache. However, synchronization functionality was not implemented. The proposed systems require continuous and reliable Internet connection during downloading of contents to memory cache as a result they favor learning environments with sufficient resources and reliable Internet connectivity.

Lujara [11] proposed Compact Disk Read Only Memory (CD-ROM) for offline delivery; however the proposed solution cannot accommodate the needs due to rapid growth of the amount of information and increased number of e-learning users. Furthermore, client-side proxy architecture for supporting offline use of learning contents and bracing approach for increasing web server performance was proposed [3, 12]. However, pre-fetching and caching of contents to local memory were done automatically by the system owing to the filling of the cache with documents without any prior knowledge of the user. For third world countries, taking Tanzania as an example; the extension of learning contents

delivery to mobile computing devices and implementation of cost-effective solutions for HLIs within resource and bandwidth constrained environments is still an open research topic.

This paper proposes a Cost-effective Mobile Based Learning Content Delivery approach for resource and network constrained environments. By synchronizing contents from remote to local server for offline use, it is possible to reduce the cost of bandwidth usage, server's workload and Internet usage overhead. In the end, the proposed approach intends to improve the quality and participation of learners as well as facilitating mobility and portability in learning activities.

The rest of this paper is organized as follows: Section II outlines design requirements; Section III presents the proposed system architecture; Section IV presents contents synchronization and caching; Section V discusses results; and Section VI concludes the paper while giving future works.

II. DESIGN REQUIREMENTS

Portable computing/communication devices are essential for mobile based e-learning content delivery and accessibility in HLIs. The most significant feature in the mobile environment is mobility itself. It assists users to be in connection while are outside the reach of conventional communication spaces. In the context of learning environments, mobility can be conceptualized in terms of ability to access learning contents anytime, anywhere without the restriction of time and space. The significant design requirement for the proposed system is the synchronization of learning contents from some remote server to a local database (mobile database) to fulfill the following purposes:

- ✓ Extend learning contents delivery and accessibility to mobile computing devices;
- ✓ Synchronize learning contents to the mobile devices;
- ✓ Reduce the cost of bandwidth usage;
- ✓ Enable offline access to learning contents;
- ✓ Enable ubiquitous access to learning contents anywhere, any time without the restriction of time and space;
- ✓ Reduce internet usage overhead and servers' workload;
- ✓ Improve the quality and participation of learners in learning activities.

When the proposed system; that is Mobile Learning Contents Delivery System (Mobile-LCDS) is installed in users' access devices; it will provide the mobile with a user interface to interact with the system and persistent storage for temporary storage of synchronized contents. When a user makes a request; the Application Programming Interface (API) accepts the request by GET or POST methods; then it interacts with PHP classes to get data from database or store data into database; and finally return the output to the requesting user/device in JSON/XML format which is human-readable. The user can synchronize contents from the remote database when internet is

available; the persistent storage stores synchronized contents locally in mobile device for offline use.

III. PROPOSED SYSTEM ARCHITECTURE

Figure 1 represents the proposed Mobile- LCDS architecture. The proposed system consists of two main parts; the backend and the frontend. The backend consists of a database management system and a web server. The implementation of the backend use Open source relational database management system (MySQL) for main storage and server side-scripting language (PHP). The frontend part is the mobile application running on android mobile operating systems deployed in user's mobile computing devices (smartphone, tablet, etc). This part of the system is used for accessing learning contents. The applications for Android are developed in Java Programming Language and executed in a Virtual Machine (VM) called Dalvik VM [13]. These technologies are most preferred because, the system developed using these technologies has user-friendly interface, easy to manage and maintain, and are widely used and available. The backend consist of the logical/business layer and storage/data layer, and the frontend consist of the presentation layer. The details are as follows:

- a) **Presentation layer:** This is the topmost layer of the application that provide interface between user and the system. It consist of the following building blocks:
 - *Mobile application interface:* The frontend part is the mobile application running on android mobile operating systems deployed on the user's mobile computing device. The mobile application interface is used for accessing learning contents.
 - *Persistent temporary storage:* SQLite database is used for storing synchronized learning contents for offline use.
 - *HTTP connection Manager:* The purpose of an HTTP connection manager is to serve as a factory for new HTTP connections, to manage life cycle of persistent connections and to synchronize access to persistent connections making sure that only one thread can have access to a connection at a time.
 - *Synchronize and cache:* It synchronizes (Sync) learning contents from remote server and store into local database (mobile database) for offline use.
 - *Web interface:* Serves the purpose of uploading large files that can be difficult to be uploaded using mobile devices.
- b) **Logical (business/data access) layer:** The purpose of business layer is to control an application's functionality by performing detailed processing. This layer coordinates the application processes commands and makes logical decisions. It moves and processes data between the presentation layer and data layer. Thus the logical/business layer is the implementation of a web server which can be done by apache server to serve the purpose of content management.
- c) **Storage/data layer:** This layer consists of database servers that form the main storage. This layer keeps data neutral and independent from application servers or business logic.

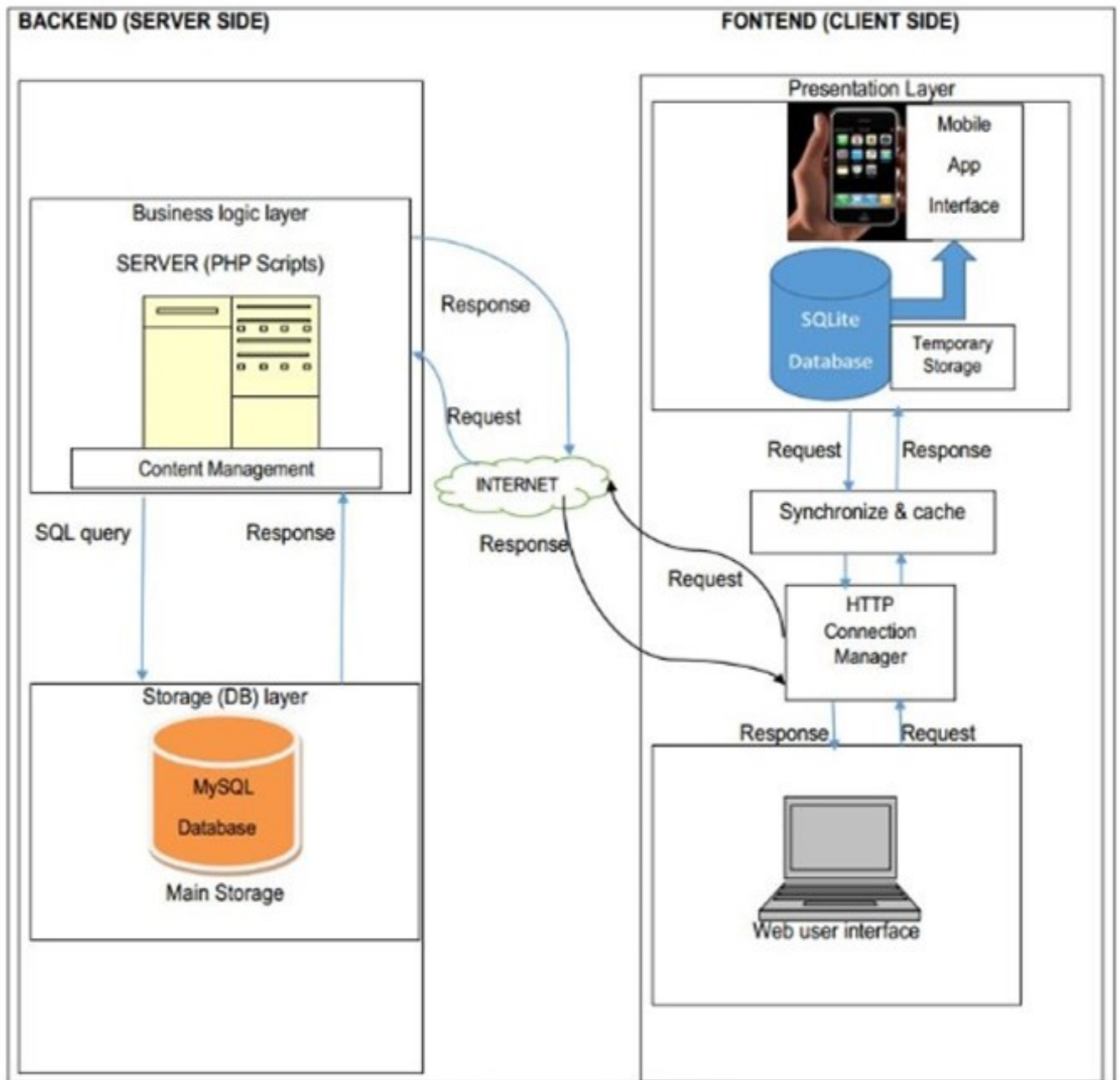


Figure 1: Mobile-LCDS proposed architecture

IV. SYNCHRONIZATION AND CACHING

This part discusses an alternative approach (synchronize and cache) for learning contents delivery and accessibility without highly depending on the Internet. The advancement in mobile application provides an opportunity of being able to work offline. Synchronization for data-driven applications means that a subset of the application data can be stored locally in the access device and data synchronization mechanism is

implemented to keep the local database and server data (main storage) in a synchronized state. Cache means temporary storage of synchronized data. The goal is to find an efficient and cost-effective approach for learning contents delivery in HLIs with resource and network constrained environments. In Figure 2 we consider the learning contents A, B, C, D, E, F, G, H, I, J... stored in the main storage and the contents A, B, C which have been cached to persistent temporary storage.

Without the synchronization and caching policy the user accesses contents from the main storage and will need continuous internet connection which is costly in terms of bandwidth connection and usage. Also it takes long time to access content from the main storage due to fact that it highly depends on the Internet, as a result it is affected by the following factors:

- **Webservers 'Performance':** Different webservers types used for hosting contents, depending on its technical specifications, could have different processing power. For example, webservers configured with high-powered central processing units and huge amounts of memory would have superior processing capability, compared to those that are insignificantly configured. Also servers could still be overloaded when the number of concurrent accesses exceeds the webserver's capability.
- **Location of webservers:** Typically, webservers are hosted on the backbone of networks to facilitate the delivery of content. In the occasion where the webserver is hosted at a remote site (for security/ management purposes), a leased line connection is required to a network service provider. In this case, the provided bandwidth of the leased line becomes the bottleneck if users are demanding more bandwidth than available capacity.
- **Firewalls and Security:** Where security features are installed in a network, the investigation and filtering of packets with every additional layer of firewall may decrease effective throughput of the system.
- **Internet speed:** The internet speed can vary depending on the differing expectations of speed of download and access of various end-users hence causing some delay in contents delivery.

Majority of HLIs in third world countries like Tanzania face the challenge of resource and network constraints as a result delivery and accessibility of learning contents using internet based learning system become a challenge. Figure 2 represents

contents synchronization and caching, an alternative approach for content delivery and accessibility without heavily depending on the internet connection. For the contents that have been synchronized and stored locally in access device for future use, every time a user needs such contents, is able to access it offline from temporary storage.

The storage capacity of most mobile computing devices is large enough to store huge amount of data. Randell [14] reported that; Apple's reasonably priced iPhone, the 5c, is the most generous of the 16GB phones recently tested, giving the user 12.6GB of memory (79% of the total space) to play with. Also, Google's new Nexus 5, which runs on the Android operating system like the S4, offers relatively free 12.28GB (77%) of usable space, the iPhone 5s provide 12.2GB (76%) of usable storage, Samsung Galaxy S4 has just 8.56 GB and others have reasonable memory space that can allow storage of learning contents. This is a promising indicative possibility for storing huge amount of data locally in mobile computing devices. This study employs the opportunity brought by android built-in SQLite database for temporary storage of synchronized contents. The SQLite database file has a maximum size of 140 Terabyte (TB). However, the memory size of phone will limit how much data can be retrieved from a query.

With synchronization and caching policy the proposed system (Mobile-LCDS) would support offline accessibility of learning contents. When the Internet is available; the system synchronizes the contents from the permanent storage or remote server to a local database (mobile database) where they can be used offline. Accessing the synchronized contents does not require internet connection, therefore it allows the user to access the downloaded learning contents offline. Therefore the proposed system reduces the access time since no delay due to independency of internet connection; cuts down the cost of bandwidth connection and usage; alleviates servers' workload and internet usage overhead; and improves the quality of experience and participation of learners in learning activities.

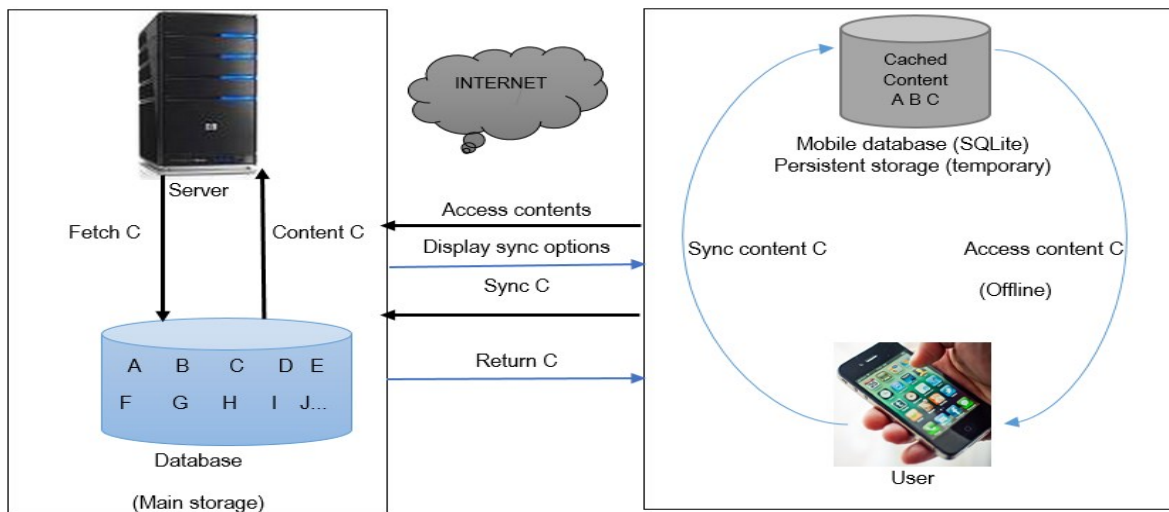


Figure 2: Contents synchronization and caching

Figure 3 represents the Mobile-LCDS client application that displays sync options based on users' needs. The system allows a user to sync learning contents in a semester basis, yearly basis or sync all contents – depending on the device's storage capacity. The sync options are significant for allowing user to sync only required contents as a result it avoids filling the local database (cache) with unnecessary contents.

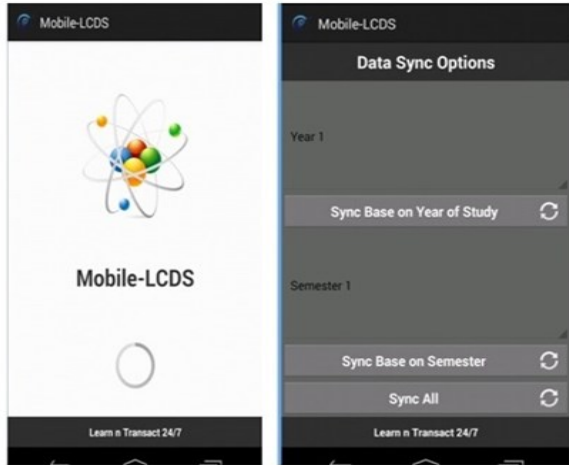


Figure 3: Mobile-LCDS Client application

Synchronizing learning contents locally in mobile devices has several advantages including: reducing the cost of bandwidth connection and usage; ability to access learning contents anywhere, any time without the restriction of time and space; reduction of the internet usage overhead and servers' workload; and speedy and smooth access to learning content due to the fact that all required contents will be available in mobile device –thus the user does not need to re-connect to the internet. Furthermore, the extension of learning contents delivery and accessibility to mobile computing devices will: improve the quality of experience and participation of learners in learning activities; encourage collaboration among students and instructors using messages and discussion forum regardless of their physical location and time; and reduce travel time and cost that would otherwise be spent on traveling seeking for learning materials.

V. RESULTS AND DISCUSSIONS

This paper showed how the opportunities brought by mobile technologies can be used to enhance learning contents delivery and accessibility in resource and network constrained environments. The paper proposed a Cost-Effective Mobile Based Learning Content Delivery System that bridges the gaps in existing e-learning systems by allowing significant bandwidth savings through offline use of learning contents. The proposed system synchronizes learning contents locally in mobile devices when the Internet connection is on. The synchronized contents can be used offline as a result; it reduces the cost of bandwidth connection and usage, reduces internet usage overhead and servers' workload, improves e-learning

system performance, speedy internet access and improves the quality of experience and participation of learners in learning activities.

Comparing to existing Internet based learning system like Moodle, the proposed system do not highly depend on the Internet connectivity as a result it can benefit HLIs within resource and network constrained environments, which is the major problem facing majority of HLIs in third world countries. For the proposed system, learning experience is considered in terms of offline accessibility; mobility and portability; increased motivation in learning activities; increased collaboration through integration with social networking tools; social interaction (discussion forum, live chat); cost-effectiveness and ability to learn anytime, anywhere. Two cases were considered for learning outcome; personalized and innovative learning. For personalized learning; learning outcome could be improved skills and acquisition of new skills while for innovative learning; learning outcome could be improved social skills, quality and participation of learners in learning activities. The proposed system is underpinned by the traditional learning environment and also supported by effective learning policies, rules and regulations, human resources, the Internet and technologies to facilitate access of learning materials.

In order to improve e-learning content delivery and accessibility under limited resource settings, HLIs in developing countries, like Tanzania should effectively make use of innovative and emerging mobile computing technologies which are relevant to their respective environments. Successful implementation of a blended mobile-learning requires a strategic approach which should be owned by the university management, academic staff and students as well as other stakeholders. The approach should at least take into account significant issues including pedagogy; mobile infrastructures; appropriate mobile content authoring technologies; human resources; m-learning policy; training of staff and students; integration of e-learning, m-learning and ICT / digital literacy into HLI's curricula.

VI. CONCLUSIONS AND FUTURE WORKS

Even though internet based learning management system exists, persistent internet connectivity in third world countries like Tanzania is still a major challenge for both public and private HLIs. It has been found that majority of HLIs in Tanzania do not utilize the opportunity brought by e-learning due to the high cost caused by persistent internet connection requirements. Majority of third world countries, face similar problems of resource and network constrained environments.

This work has designed a Cost-Effective Mobile Based Content Delivery System to facilitate learning contents delivery in resource and network constrained environments. The system employs the opportunity brought by android built-in SQLite database for temporary storage of synchronized contents for offline use. The results of this work can be applied to other third world countries because they experience similar challenges as Tanzania. While owning and maintaining ICT infrastructure for HLIs has many challenges including cost of hardware, software

and human-ware, the growth of mobile phones bring new opportunity for them to be used for education purpose. The future work is to implement and test the system in real working environments. The system would be tested using black box testing technique to deduce errors. From the mobile side, usability evaluation would be conducted using different mobile computing devices. The System Usability Scale questionnaire, a recognized usability instrument, would be used to measure the usability and user satisfaction of the system.

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