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LoColms: an innovative approach of enhancing traditional classroom form of education by promoting web-based distance learning in the poorer countries

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Abstract: There have been numerous attempts recently to promote technology based education (Shrestha, 1997) in the poorer third world countries, but so far all these have not provided a sustainable solution as they are either centered and controlled from abroad and relying solely on foreign donors for their sustenance or they are not web-based, which make distribution problematic, and some are not affordable by most of the local population in these places. In this paper we discuss an application, the Local College Learning Management System (LoColms), which we are developing, that is both sustainable and economical to suit the situation in these countries. The application is a web-based system, and aims at improving the traditional form of education by empowering the local universities. Its economicability comes from the fact that it is supported by traditional communication technology, the public switching telephone network system, PSTN, which eliminates the need for packet switched or dedicated private virtual networks (PVN) usually required in similar situations. At a later stage, we shall incorporate ontology and paging tools to improve resource sharability and storage optimization in the Proxy Caches (ProCa) and LoColms servers. The system is based on the client/server paradigm and its infrastructure consists of the PSTN, ProCa, with the learning centers accessing the universities by means of point-to-point protocol (PPP).

Key words: LoColms, Web-based distance learning, Ontology, Paging, PSTN, Proxy caches, PPP
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INTRODUCTION

Education in general is at difficult crossroads in many developing countries, particularly the least developed and low-income countries. The emergence of distance education provides an important way to address their concern, but for reasons ranging from economic aspects to the level of sophistication of the Information Technology (IT) systems, technology supported education might delay any impact on these developing nations. The basic barriers to distance education in these countries are: 1) the lack of resources needed for meaningful development and sustenance of technology-based learning, 2) lack of infrastructures (which includes information and communication hardware systems) to support modern technologies in least developed and/or low-technology countries, and 3) the lack of continuous funding necessary to acquire or develop appropriate software and courseware on a continuous basis, and maintain, service and replace the equipment (IMFUNDO, 1999).

Politically, there have been some generous initiatives to try to make educational resources from the universities in the developed countries accessible to the developing countries, especially the least developed countries (LDCs). For instance on the African continent, the most prominent initiative has been the African Virtual University (AVU) (Turner, 1999), whose mission is to use modern information technology to increase access to educational resources throughout South Saharan Africa (SSA). The use of infor-

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mation technology will enable higher education institutions to supplement their existing programs with resources of a global "Virtual University". There exists other forms that distribute study materials either by online, broadcast or by postal service but all these lack sustainability and relevancy to the situation in these countries. The choice approach should exhibit the following characteristics: 1) high degree of sustainability; 2) high utilization of the locally available resources; 3) should be affordable to the average person in these countries.

The main advantage of the LoColms is that it addresses:

1. The financial considerations, in that there is no government funding required. Probably the governments would only come in with regulations to ensure the smooth operation of the educational system over commercially run Study Centers (SCs), as well as providing preferential treatment to the operators of LoColms;

2. The system's sustainability, which is brought about by the fact that the involved parties are the telephone companies, which is a familiar technology in these places with experienced technical staff, the local universities being sole supporters of the educational system, and operators of the LoColms study centers being the local entrepreneurs;

3. The system's affordability by the local population, which comes from the fact that since the remote students would not require any of the university's facilities for accommodation, feeding, healthcare, classroom, library, etc.; so the cost for tuition would necessarily have to be reasonably very low. As well, the costs over the telephone system are almost eliminated by the use of the ProCa, which are used to reduce latency and traffic of the study contents over the telecommunication network.

This paper discusses the sustainability, economicability and affordability and the relevancy of the LoColms in the context of poorer countries' situation.

RELEVANCY AND SUSTAINABILITY OF LoColms

Case studies (Shrestha, 1997a; 1997b) showed that so far the institutionalized forms of distance education in most of these poorer countries are in radio and/or TV broadcasts mode, and sometimes Open Universities, which are nationally controlled although they are often foreign funded, and the "Virtual University" mode, which is both foreign controlled and funded, but locally administered, whereby some institutions in the industrialized countries relay educational resources directly to the hosting universities in these countries by satellite communication. Both modes have one thing in common: Like the classroom type of education, time and classroom space constraints do still exist, but unlike the classroom type, one tutor can reach very many classrooms at a time. Especially for the TV broadcasts and Satellite communication, the costs are high and if there is no constant funding the project will fail.

Since the LoColms is a web-based system, it is not constrained by space or time. Learners in the system can learn at any time and from anywhere, although because of the characteristic of LoColms in providing video materials instead of texts or audio, usually the case with the Internet online courses, the learners are organized in study centers (SCs), where they can be provided with broadband communication links. We recommend optical cables or at least DSL or ISDN (PRI) connections between the PSTN central offices and the SCs and the universities. The class sessions from the universities' multimedia theaters are recorded and saved into the LoColms servers, and the remote learners can download the unedited video recorded class sessions and follow the class sessions, giving the learner a feel of belonging to the class.

The problem with the telephone system is that once a connection has been established, the channel remains connected even when the line is idle, which makes the telephone system very costly. LoColms solves this problem by employing ProCa, which serves as a proxy server for all the contents downloaded, and after the download has been completed, the PSTN line is automatically disconnected, and the subsequent learners would study the saved materials from the SC LAN.

The advantage of the system by the PSTN over the Internet (a packet switched system) is that Internet has a too narrow bandwidth to serve video contents of big sizes, and it is also unreli-

able, because IP protocol just offers "best-effort" services, while the PSTN network's QoS ensures a fixed delay and no-loss guaranteed service.

LoColms expected performance

The system targets over 99% of the mainly the high school leavers (hsl), since in most of the LDCs' colleges, the enrollment stands at much less than 1% of the hsl. The system will have a greater impact in urban areas, due to the demographic distribution, where there is a higher teledensity, and approximately about 10% of the hsl dwells. If we assumed a normal distribution and one standard deviation (1 SD) for the 10% of hsl to be active members of the system, on the basis of those who can be online regularly, in Rwandan towns/cities (MFEP, 2000) the system can support over 13 600 users each year, which is about 188% of the total college capacity (The total capacity for the overall colleges' resident students in the country was 7224).

Since the system would be commercially implemented and would be cheap and indiscriminate by age and gender, the numbers of the system users will grow fast, by a logistic growth order;

$$dP/dt = rP(1 - P/K)$$

The growth would have exponential characteristic but constrained at a value K, depending on the distance from the CSs as well as financial capabilities of some families. In the case of Rwanda (MFEP, 2000), if the growth would be constrained at about 20% of the hsl, the institutions' sizes would increase (in virtual terms), by 277%, without any major variation in the universities' existing facilities.

LoColms system description

LoColms is a web-based Asynchronous Interactive Educational system built on Java technology, and it enables the SCs to access the local universities offering the courses by means of Point-to-Point Protocol (PPP), a link layer protocol suite designed for moving datagrams across serial point-to-point links initially deployed over short local lines, leased lines, and plain-old-telephone-service (POTS) using modems, but as new and higher speed lines are introduced, PPP is easily deployed in these environments as well (Perkins, 1993). The application architecture is shown in Fig.1.

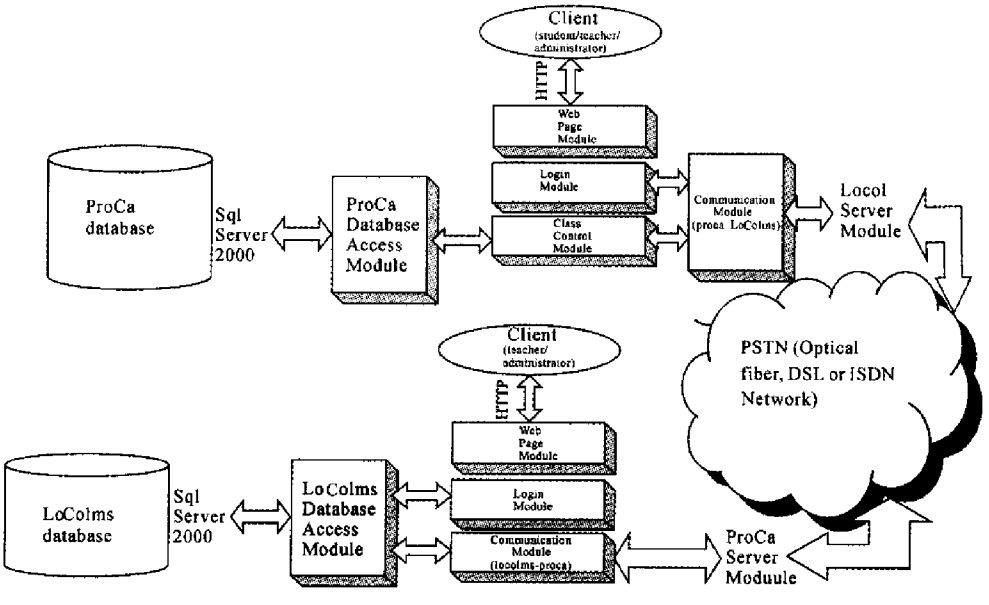

Fig.1 System architecture

Because the system supports mainly video recorded class sessions saved into the LoColms servers of the university, broadband links, such as the Optical cables or DSL between the SCs' LANs, the universities' LANs, and the telephone central offices are required. As well, SO-

NET/SDH links between the PSTN central offices are assumed. The LoColms system records the Class Attendance for a particular subject each time a student's login is successful, but does not download the selected topic for study before it ascertains the content is not already saved on the ProCa from the previous downloads by the earlier students. In other words, the telephone line is only in use during the login for administrative procedures, and for downloading the contents only when the content does not exist in the ProCa.

The Course Structure Format (CSF) and Course "Packaging" in the LoColms is emulated in the ProCa, although the ProCa requires contents by blocks of class session units of a topic, in the order these units were taught. Anyhow, the elements block, Assignment Unit (au), and objective will satisfy the prerequisites and completionReq of the CSF (SCORM, 2000). The learners will be served with topic assignment units (Tau) according to the prerequisites and completionReq procedure for each topic, (Tau_1&Tau_2 &...&Tau_x), with an after Tau exercise to mark the completion of a Tau, and the period should be over 45 minutes, and a finished Tau is recorded in the LoColms server against the topic of a given subject.

LoColms application brief description

The application, as shown in Fig.2, consists

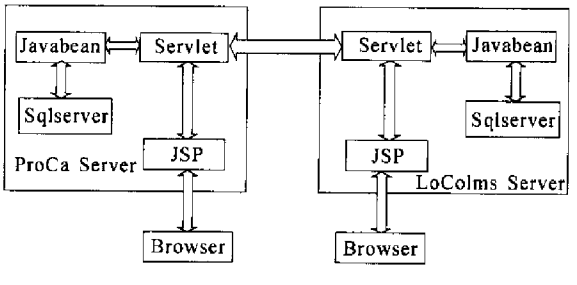

Fig.2 system structure

of two servers, the ProCa server and the LoColms server. Below we indicate the key sevlets involved (the aspects of teacher and administrator are not discussed in this paper):

1. For the **ProCa Server** (package com.proca.servlets), there are the LoginControl.java and the ProCaLoginControl.java's functions are to control the login of ProCa server and University by forwarding the request to the LoColms server; ChooseTopic.java's function is to return the courses list, and receive request from chooseTopicToStudy.jsp and forward the request to ProCaChooseTopic.java in the ProCa server and receive the response from it, then forward the response to the chooseTopicToStudy.jsp and show the topic that has been selected for study; UpdateStudentInformation.java's function is to update the student's personal information. It receives request from updateStudentInformation.jsp and forwards the request to the ProCaUpdateStudentInformation.java in the LoColms server; CheckAttendance.java's function is to check the student's attendance. It receives request from chooseTopicToStudy.jsp and forwards the request to ProCaCheckAttendance.java in the LoColms server, then receives the response and decides on whether the student has the right attendance; TopicControl.java's function is to decide on whether or not to download the topic file from the LoColms server. First, it checks to see whether the ProCa server has the topic file. If not, it forwards the request to ProCaTopicControl.java in the LoColms server to download the topic file from the LoColms server. If it has, it forwards a request to the ProCaTopicControl.java in the LoColms server to check whether the topic file is updated. If not, it downloads the latest update file of the topic; ClassControl.java's function is to control the study of the class and record the time spent on the study. This receives request from studyTopic.jsp and forwards the request to ProCaClassControl.java in the LoColms server to record the time when the student began the study; ExerciseControl.java's function is to provide the exercise file from the LoColms server (in the package, in each Tau an exercise file is included). It receives request from finishStudy.jsp; RecordAttendance.java's function is to record the attendance of the class. This receives request from doExercise.jsp and forwards the request to ProCaRecordAttendance.java in the LoColms server to record the attendance of the class.

2. In the **LoColms Server** (package com.locolms, proca.servlets), ProCaLoginControl.java's function is to control the login from the ProCa server. This receives a request from LoginControl.java in the ProCa server and calls the Javabean in the LoColms server to check the log-

in; then returns the response to LoginControl.java in the ProCa server; ProCaChooseTopic.java's function is to return the courses list to let student choose. Receives request from ChooseTopicToStudy.java in the ProCa server and call the Javabean in the LoColms server to return the courses list and forward the response to the ChooseTopicToStudy.java in the ProCa server; ProCaUpdateStudentInformation.java's function is to update the student's personal information. It receives request from UpdateStudentInformation.java in the ProCa server and call the Javabean in the LoColms server to update the student's personal information. Then it returns the flag of whether the operation was successful to UpdateStudentInformation.java in the ProCa server; ProCaCheckAttendance.java's function is to check the student's attendance. It receives a request from CheckAttendance.java in the ProCa server and calls the Javabean in the LoColms server to check the student's attendance. Then forwards the response to CheckAttendance.java in the ProCa server; ProCaTopicControl.java's function is to decide on whether to download the file from the LoColms server, receives request from TopicControl.java in the ProCa server and calls the Javabean in the LoColms server to find the topic file and check the update. Then return response to TopicControl.java in the ProCa server; ProCaClassControl.java's function is to control the study of the class and record the time spent on the study. It receives a request from ClassControl.java in the ProCa server and call the Javabean in the LoColms server to record the time when the student begins the study; ProCaExerciseControl.java's function is to decide on whether to download the exercise file from the LoColms server; and the ProCaRecordAttendance.java's function is to record the attendance of the class. It receives a request from RecordAttendance.java in the ProCa server and calls the Javabean in the LoColms server to record the attendance, then returns the response to RecordAttendance.java in the ProCa server to show whether it is successful.

Below is the code segment for the study control:

```
package com.proca.servlet;
...
public class studyControl extends HttpServlet
...
public void doGet(HttpServletRequest request, HttpServletResponse response)
    throws ServletException, IOException
{
HttpSession mySession = request.getSession(true);
TopicUnit unit = (TopicUnit) mySession.getAttribute("unit");
Courses course = (Courses) mySession.getAttribute("courses");
    ...
{
Exercise exe = course.getExerciseOfTopicUnit(unit.getID());
    ...
response.sendRedirect("unitStudyWithExe.jsp");
}
```

Fig.3 (see next page) shows a student Tau selection explorer screen shot. After the student has made the right selection of the particulars, automatically the application will guide the learner to the right Tau.

PROXY CACHE STUDY CONTENTS MANAGEMENT

The contents, video recorded classes, are arranged in units of 60 minutes consisting of 45 minutes, (45 MB file) of video recorded class session and 15 minutes for the end of Tau exercise. If a proxy cache storage capacity of, say, 100 GB was used to the full capacity, there would be about 2000 units, or 2000 different subject topics hosted on one ProCa, or 2000 students simultaneously studying from the system on a single SC LAN. If the size of one SC had, say, 20 PCs, with all the 20 computers busy throughout the day (from 8:00 to 22:00 hours), it would accommodate nearly 300 learners (1/6 of the capacity or 13 GB) per day, for worst-case scenario. But this is not a likely scenario, especially for popular courses. Most likely several learners will be studying same courses, thus the likelihood of sharing contents is high. The basic purpose of caches is encourage sharing of contents. Consider a subject A (SA), having several Taus:

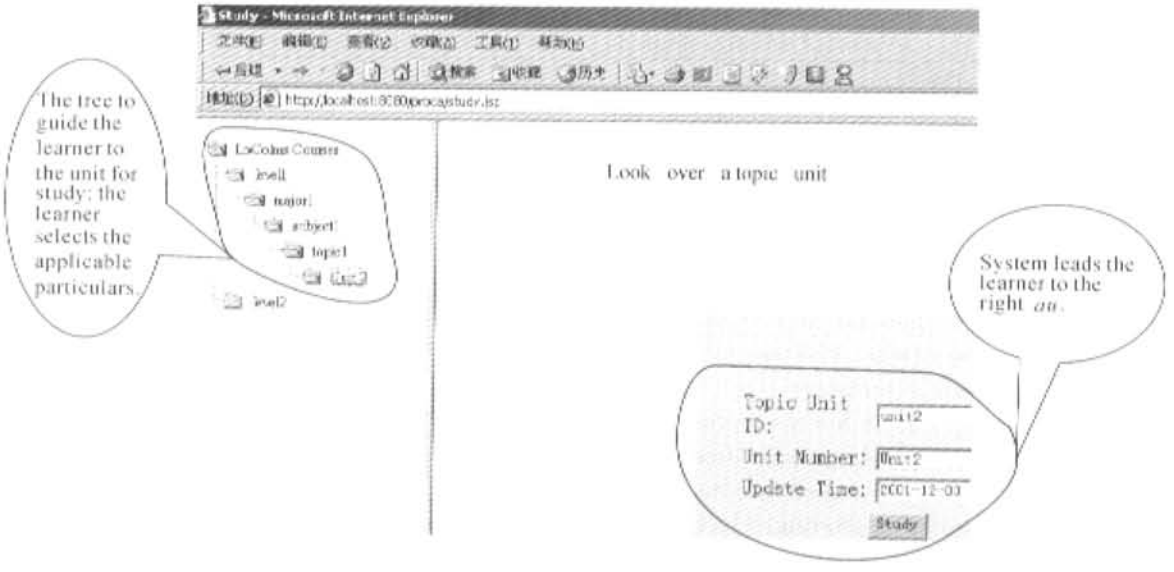

Fig.3 Student Tau selection explorer screen shot

$$SA = \{Tau_1, Tau_2, \ldots, Tau_N\} \quad (1)$$

For, a Tau_j, a certain number of students, NA_i, may access it (share the copy). The greater the NA_i for Tau_j, the fewer the copies of contents residing in the ProCa. Thus:

$$(Tau_j) = \begin{cases} NA_i = 1 \text{ (unshared contents)} \\ NA_i > 1 \text{ (shared contents)} \\ NA_i = 0 \text{ (no contents in cache)} \end{cases} \quad (2)$$

The over all contents in the proca would be:

$$\sum Tau_j = \sum (Na_i > 1) + \sum (Na_i = 1) \quad (3)$$

According the Eq.(2), if the shared contents dominate, then according to Zipf's law (Harremoes and Topsoe, 2002), the hit ratio for most popular SA would be estimated to be 20% to 80%, which determines the degree of infrequent download of contents from the locolms server over the PSTN network.

Also, even in cases where the sharing is not possible, the cost of downloading a fresh content is still economical, especially if a broadband infrastructure is used. For example, with an ADSL, configured at 6 Mbps, downloading a topic unit of 45 minutes would take less than 3 minutes, which according to local telecommunication charges, is very minimal. In Rwanda, for instance, it was at 14 francs (or US $ 0.03) per minute, as compared to the cost of about 300francs (or US $ 0.67) for Internet access charge in the Internet bars in Kigali, in 2001.

To optimize the ProCa storage capacity, the system will only be concerned with the contents regardless of the college the contents are obtained from. In other words, it doesn't matter from which University the topic was downloaded. The learners studying from different universities but studying the same courses will share contents. This is to avoid crowding up the ProCa by similar contents because they are originating from different institutions. ProCa will keep only the copy of content of the institution from where the download was first made. The system will therefore keep track of the less frequently studied contents, so that they can be removed, probably employing the least frequently used (LFU) replacement policy. According to the studies carried out (Young, 1994), the LFU has the best competitive paging ratio overall the other replacement policies. As a result, effectively, the over all contents in the ProCa storage would be shared:

$$\sum Tau_j \approx \sum (Na_i > 1) \quad (4)$$

CONCLUSIONS

Certainly the LoColms is one of the many efforts to bridge the digital divide between the

highly industrialized and the least developing societies. Extending the access of quality educational resources of the universities of the west cannot heal the educational deficiencies of the individual LDCs. The LoColms application has the potential to improve the weak Traditional Education System in the LDCs, by employing web technology tools, without being concerned about the characteristic hindrances, namely the disadvantages in terms of financial and technical expertise aspects in the LDCs. The case of Rwanda was used for elaboration purposes.

The paper discussed the numerous benefits of the LoColms increasing college enrollments, as well as, creating new jobs, popularizing IT environment in a country, upgrading telecommunication infrastructure and empowering local universities to participate in improving the traditional form of education in LDCs. The system's high degree of sustainability, and the way it addresses the economic concerns in promoting the web based distance education to enhance the traditional form of education in the LDCs was also discussed. It uses the available technologies, yet is flexible enough to deploy the most sophisticated web related technologies, especially for resources distribution and retrieval, which will become more inevitable as the resources increase. There is no country that would fail to implement it.

FUTURE WORK

At this stage we have assumed uniform situation in every university. But every university may have a different naming scheme for departments, majors, courses, etc., but without necessarily any significant difference in the contents. Also, different university may use different languages for medium of communication, such as English or French. We shall include the ontology tools, so that the system could resolve these discrepancies.

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