Telemedicine
and e-Health

Perspective

Improving Epidemiologic Surveillance and Health Promoter Training in Rural Latin America through Information and Communication Technologies

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ABSTRACT

This paper presents two technological developments oriented to increase the efficiency of the epidemiologic surveillance system and to improve the diagnostic and therapeutic capabilities of the rural establishments with only e-mail connectivity through wireless systems. The Telematics Department of the University of Cauca has developed a computerized epidemiologic surveillance system for the collecting, sending, processing, visualization, and feedback of epidemiologic information at national level. The use of the system in a pilot area has solved the problems of subregister, increasing the volume of data colection in 15%. The complete epidemiologic system is currently being implemented in 22 health care establishments in the Department of Cauca in Colombia. Likewise, the Technical University and Carlos III University of Madrid have developed a distance training system with a high-usability interface both for students and teachers. The system includes authoring, distribution, tracking, and visualization of courses synchronized through electronic mail messages in a clear way for the user. Both systems use a creative combination of e-mail and XML (eXtensible Markup Language)-based technologies, ready to be used through slow, intermittent, and asynchronous communication systems.

INTRODUCTION

ONE OF THE MAIN PROMISES OF TELEMEDICINE has been to support the improvement of health care services in isolated and scattered communities through the use of new information and communication technologies (ICT). However, most of the current projects are mainly oriented to the exchange of information and medical images between relative high-level hospitals, or focused on the interconnection of institutions—independent of the public health system—with highly specialized centers to obtain a second opinion.

On the contrary, the objective of Enlace Hispano Americano de Salud (EHAS) Program (a

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consortium of several institutions from Europe and Latin America working in rural telemedicine; see www.ehas.org), is the development of communication systems and information exchange services for the primary health care facilities of the public health system in Latin American countries such as Peru, Colombia, and Cuba. The actuation areas are characterized as mountainous or rain forest/jungle with great difficulties in access to infrastructures (usually without electricity, roads and even phone service).[1]

The technologies developed by EHAS have provided innovative solutions for voice and data communications in rural areas lacking any telephone system. The tools providing e-mail, web, and Voice over Internet Protocol (VoIP) through wireless systems (very high frequency [VHF], high frequency [HF] and wireless fidelity [WiFi]) were developed under the concept of appropriate and low-cost technology. Likewise, the main services running on those communication networks (epidemiologic surveillance, distance learning, reference and back-reference of patients, and teleconsultation) have been thought to solve the main problems of the isolated health staff.

The main goals of the developments we describe in this paper are: (1) achieving better efficiency in the epidemiologic surveillance system (providing timely accurate information, avoiding zones without any data, and allowing fast feedback to the rural area); and (2) improving the diagnostic and therapeutic capability of the rural establishments through a continuous processes of training of the rural healthcare personnel.

With respect to the first goal (improvement of the epidemiologic surveillance system), we reviewed existing epidemiologic surveillance systems using ICT: experiences in different developed countries,[2] other telemedicine experiences and systems focused in early disease warning,[3–5] complete computerized systems,[6] common tools to manage epidemiologic information[7]; Latin-American experiences,[8–11] as well as national efforts in this respect.[12] We could conclude that most systems are oriented to the analysis of epidemiologic data, and specially designed for one specific vertical program. No system has shown specific attention to the problem of the collection of epidemiologic data in reliable and complete form, especially in rural communities with communication problems. This is the foremost contribution of our epidemiologic surveillance system: the development of appropriate technologies, easily maintainable and configurable, using low-cost and open-source technologies, and carefully designed for the social, economic, and public health reality of the zones of intervention of the EHAS Program.

In relation to the second goal (improvement the diagnostic and therapeutic capability of the rural personnel through remote training), the systematic revision of previous experiences has not shown good results. Systems based on videoconferencing for training, such as the Global Development Learning Network (GDLN), which broadcasts educational multimedia contents through satellite, need return paths that are difficult to find—or too expensive—in the countryside. Web-based training (WBT) systems provide more flexibility, reducing bandwidth requirements, but require permanent connections to the Internet, unavailable in zones without wired infrastructure with a reasonable cost. Most of the well-known platforms (such as WebCT) have never taken care of the low-bandwidth environments, which are the norm in developing countries.[13] Other possible alternatives would be the distribution of DVD with multimedia contents, or radio broadcasting of lessons. Nevertheless it is necessary to emphasize that these systems have a high index of student drop-out,[14,15] so they are not the best options to ensure the success of the learning experience.

There are some projects in addition to EHAS that have tried to solve the problem of connectivity in the countryside in more or less imaginative ways. The DakNet project[16] is one such project. It uses vehicles to carry electronic data. They allow the data transfer, even in high volume, but they do not allow the synchrony of the communications. Furthermore, this solution poses logistic problems and external dependencies dangerous for the project.

As a result of these limitations, the EHAS Program has developed a complete system of authoring, distribution, and tracking of training contents, that work in low-bandwidth en-

vironments, both in connected and disconnected mode, and even for users who only have connectivity by using electronic mail.

MATERIALS AND METHODS

The epidemiologic surveillance system

The Telematics Department of University of Cauca has developed a computerized epidemiologic surveillance system for collecting, sending, processing, visualization, and feedback of epidemiologic information at the national level. It conforms with the information flow in most epidemiologic systems in Latin America.[17] Information flow is shown in Figure 1. Traditionally, rural health posts (RHP) provide daily, weekly, semimonthly, and monthly epidemiologic and administrative information to their respective primary health care center (PHC) of reference. There, information is processed—in many cases manually—to obtain several consolidated reports used in the decision making at local level. In turn some reports are sent to the provincial health office (PHO) for its further analysis to a higher level of decision making. In the same way other consolidated reports are sent to the public health national level (Health Ministry).

If all the health facilities of the country could have permanent Internet connections, it would be possible to consider the design of a centralized web-based system to support the visualization and filling out of surveillance forms. Health care personnel would have access to the web forms to update the information stored in the global database. Furthermore, the surveillance responsible personnel at the distinct levels could obtain web-based consolidated reports to help decision making.

Unfortunately, health establishments within the EHAS Program have low bandwidth and intermittent connection through e-mail (mostly through VHF and HF radios). To solve this problem we designed a web system, similar to the one described above, adaptable to permanent and intermittent Internet connection. Health care personnel with permanent Internet connection could update the databases through web forms. Rural health care personnel having only intermittent conecction could fill in the web forms in their local machines and e-mail them to a server located at the reference PHC. The server automatically updates the database and sends notification to the surveillance system administrator about the updated data.

After a trial period in the Provincial Healthcare Department in Cauca, the system reduced subrecords, and provided reliable and timely information. However, classic problems in health care information systems appeared: continuous changes in the format of collecting forms, extension to new vertical programs, and the need to adapt the system to other participants in the EHAS Program (that is Cuba and Peru) with different epidemiologic systems. Those new requisites lead us to build a new version of the information system with substantial modifications in the design philosophy.

The new system was able to support automatic changes in the structure of the surveillance forms and quick adaptation to other surveillance systems. The new architecture is shown in Figure 2. The national surveillance coordinator may change the forms that will be shown to rural health care personal. The new form is automatically updated in the remote sites. The most outstanding module is the "forms editor" that generates a document "XML Schema" containing the structure of the web forms. This information, known as metadata, travels through the net-
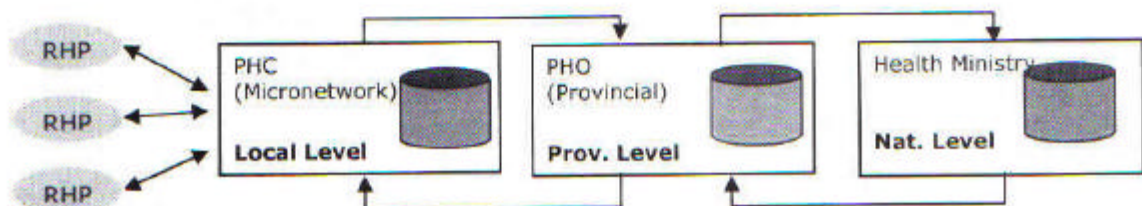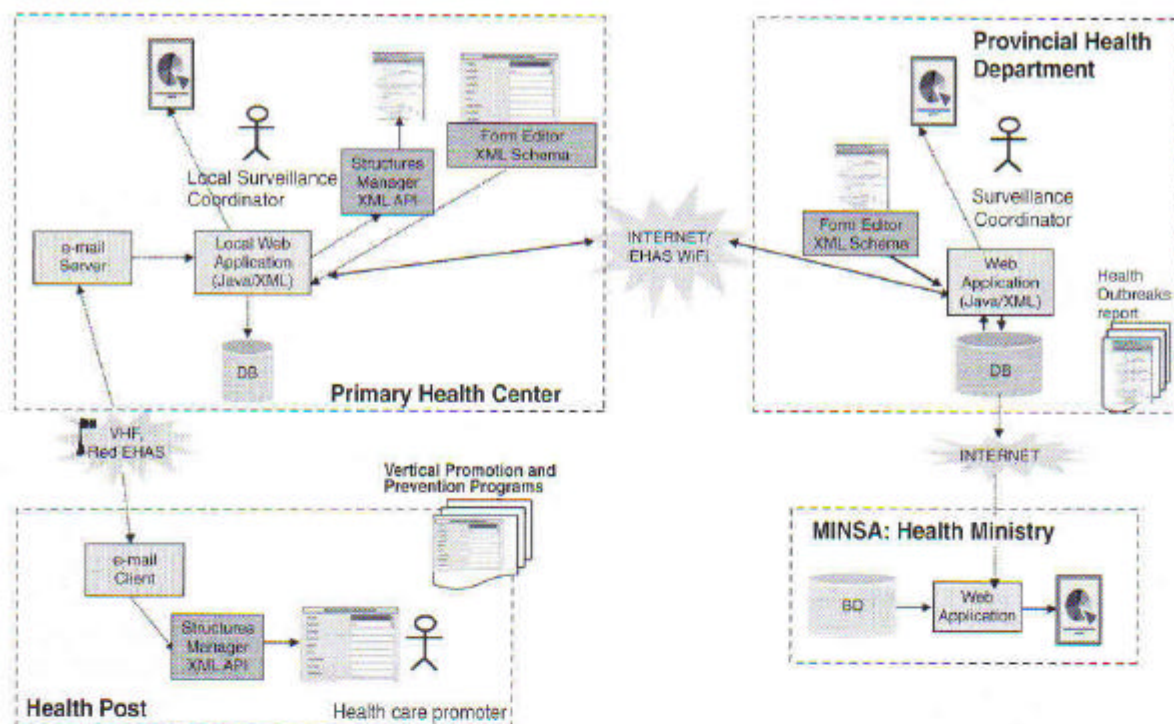

FIG. 1. The Public Health Information System.

FIG. 2. Epidemiologic surveillance system architecture.

work attached as e-mail messages and, in destination, the module named "structures manager" dynamically reconstructs the forms and show them updated.

The system is open-source software, built in Java and XML. Databases are build in Firebird, a robust relational database. The systems works with any e-mail server and e-mail client application. It also supports Linux and Windows operating systems.

The distance learning system

The Technical University of Madrid and Carlos III University have developed a distance training system specially designed to offer remote courses for students with intermittent Internet connection, and also for those who only have connectivity by electronic mail. The system include modules of authoring (content edition), distribution, tracking, and visualization.

Course materials are defined and structured in an abstract way, using XML methodology. A document-type definition (DTD) logically defines the structure of a course. The main elements of the course are title, authors, intro-

duction, chapters, sections and subsections, self-evaluations, references, bibliography, and remote examinations (Fig. 3). Inside them rich text (list, tables, etc.), and multimedia resources (images, animation, videos, sounds, flash, etc.), can be included. This content model, together with the chosen storage format (XML application) is flexible enough to facilitate different distribution models and reuse.

The authoring system has been designed with the purpose that doctors, who are non-specialists either in design or computer science, could generate, in a pseudotransparent way, an XML document that contains the course material. The edition tool is not presentation-oriented, but offers the author a series of patterns to fill in the logical components of the course. However it has a high-usability interface (Fig. 4) similar to WYSIWYG (what you see is what you get) word processors. Its development has been based in an Open Source XML editor (GenDoc) to which has been added some specific plug-ins and cascading style sheets (CSS) for the specified DTD.

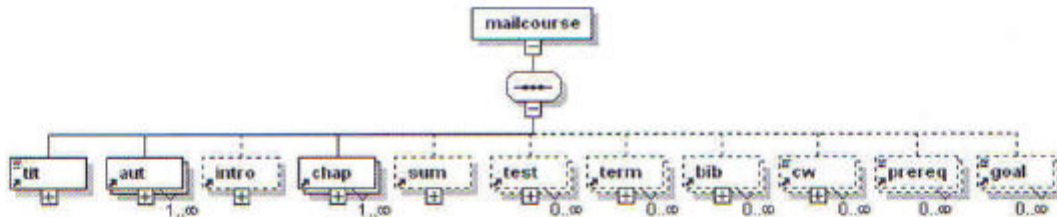Once generated, the course can be distributed in three different ways, depending on

FIG. 3. Top view of the document-type definition (DTD) of Enlace Hispano Americano de Salud (EHAS) courses.

the environment in which the student is. An XML → HTML converter allows direct visualization through a web browser. An XML → LaTeX → PDF converter produces a suitable format for printing, and finally an XML → XML converter divides the course in lessons, for sending to users through electronic mail, as can be seen in Figure 5.

Regarding tracking and visualization of the courses, a learning management system (LMS) has been developed in order to facilitate the organization of the classes, location of contents, update of permissions, tutorial process, forums of discussion, tracking of students, etc. The newness of this system with respect to those that are currently found in the market is that the platform the student works with is a particular replica of the main server. Both are synchronized in a transparent way for the user, through electronic mail messagess. This system, which is outlined in Figure 6, allows transferring the advantages of virtual classrooms (including the student's activity tracking) to isolated countryside of developing countries, with no need of real-time connections.
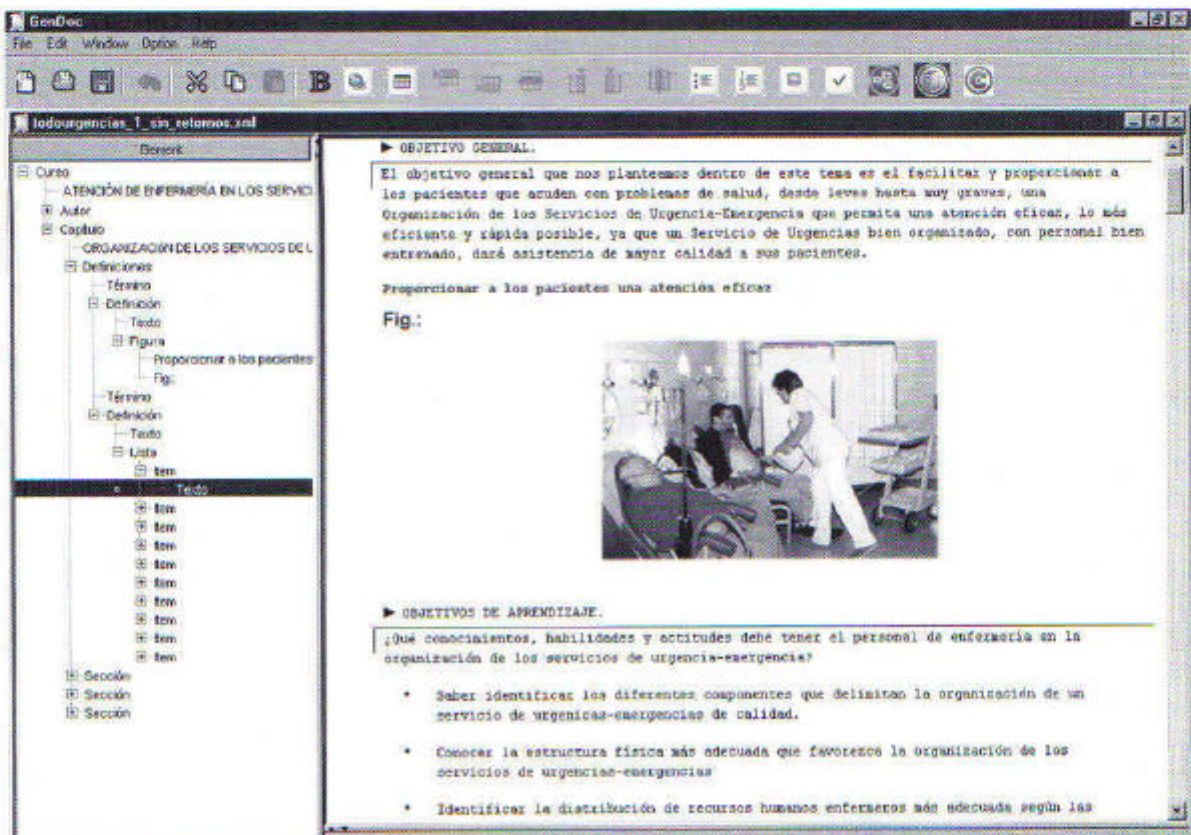

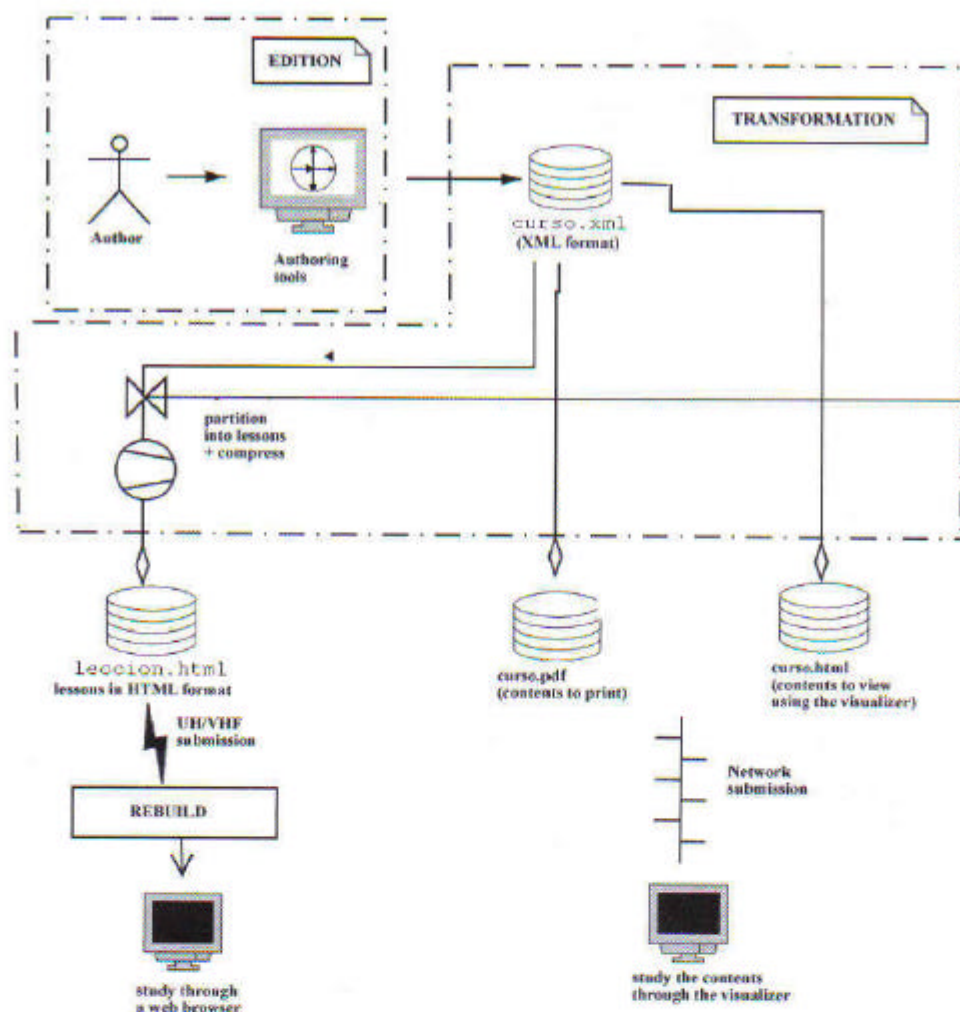**FIG. 4.** Authoring tool of Enlace Hispano Americano Salud (EHAS) courses.

FIG. 5. Possibilities of distribution of Enlace Hispano Americano Salud (EHAS) courses.

RESULTS

The epidemiologic surveillance system described has been evaluated by the Regional Health Office of Department of Cauca in Colombia.

A client software was installed in two of the RHP-dependent Hospital San Carlos. The client application allowed health care personnel to fill in the surveillance forms provided by SIVIGILA (National Epidemiological Surveillance Program) as well as the surveillance forms to collect information on the pediatric and hypertension diseases programs. The collected data was transmitted through the EHAS wireless links to the hospital. There, the information was processed by the server application and consolidated reports were obtained. The consolidated report where sent to the Regional Health Office to generate the weekly SIVIGILA epidemiologic bulletin.

The system has been operational for more than 1 year. We can conclude at this time that the Regional Health Office has solved the problems with the existence of subrecords (data volume was improved by 15%). Now the information is on time in the pilot execution zone. The system has eliminated the travel of the surveillance coordinator from the hospital to the Regional Health Office to deliver the information. The consolidation time of information is now negligible, and the reporting of information at national level is totally computerized. Until now, three changes in the structure of the epidemiologic forms were needed. These changes were done with the forms editor, not
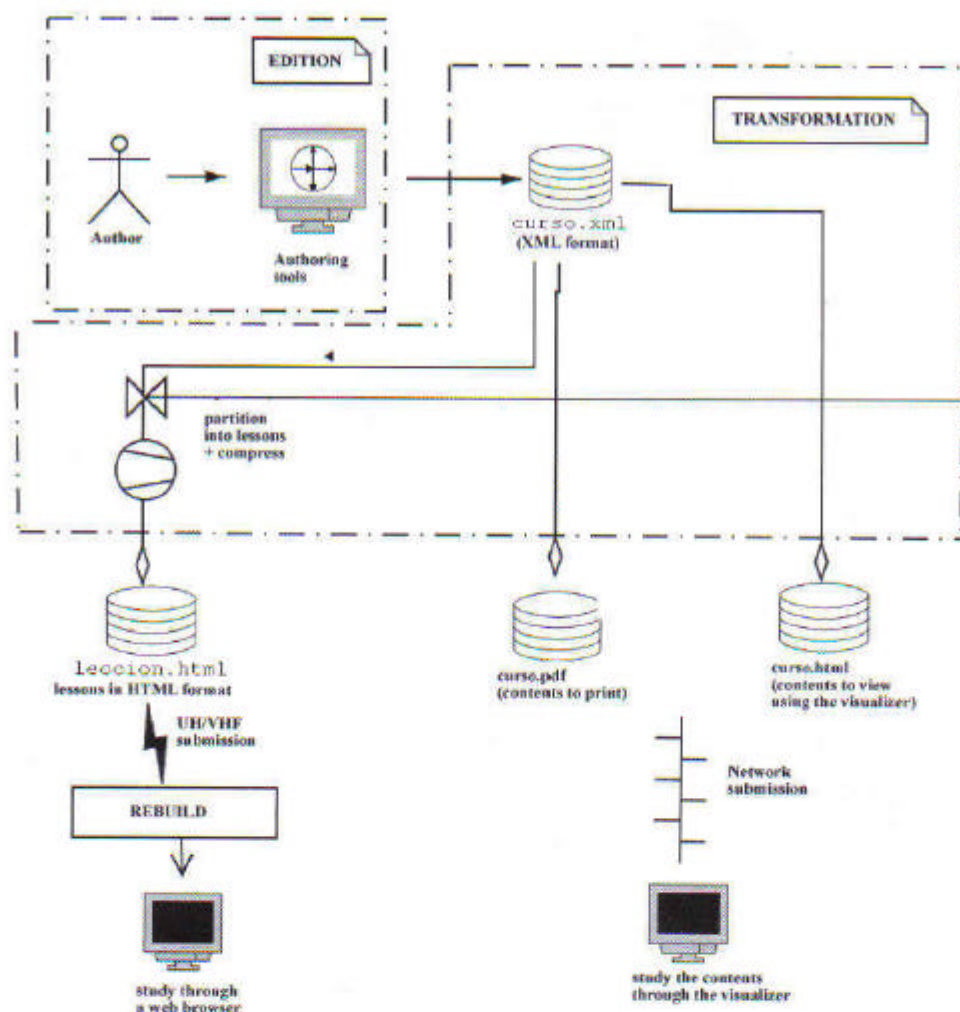
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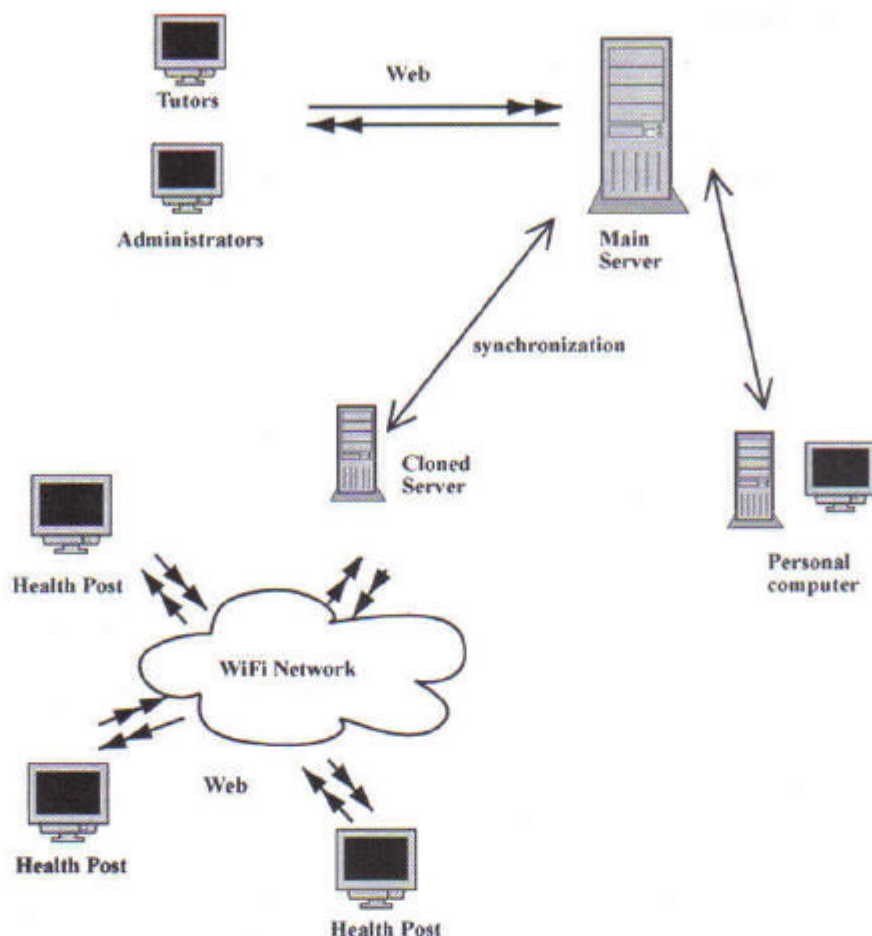
FIG. 6. Remote synchronization between learning management system (LMS) platforms.

needing more than 4 working hours to reconfigure the system. The complete epidemiologic system is currently being implemented in 19 RHPs and 3 PHCs in the Department of Cauca in Colombia.

The authoring tools have been on laboratory testing, with the production of two specialized courses ("Child Diarrhea" and "Nursery Attention in the Primary Healthcare Emergency Services") and the translation of two more ("Epidemiologic Surveillance" and "Health Education and Disease Prevention, Grass-Root Level Oriented") that were initially in MS Word or HTML format. The laboratory tests of the authoring software, transformation, distribution tracking, and visualization have been satisfactory, but the process of field tests begins right now, with a course of "Nursery attention in the emergency services" in 16 hospitals in the Dominican Republic, and several courses oriented to all the process of training for European project EHAS-ALIS in 36 systems installed in the Department of the Cusco (Peru), the Municipalities of Guapi and Timbiquí on the Pacific Coast of the Cauca Department in Colombia, and the province of Guantánamo in Cuba.

DISCUSSION

The EHAS Program has demostrated[18] that the introduction of communication technologies appropriate to local requirements solves many problems in rural primary care (improvement of emergency system, reduction of travels of health care personnel, better coodination in the distribution of drugs), and that voice and e-mail communication via VHF radio are feasible and useful for rural telemedicine (possibility of teleconsultation and access to medical information). The next step is to

check if the communication systems installed can support teletraining systems and computerized epidemiologic surveillance systems. This paper shows the work achieved to design these systems and to adapt them to netwoks with only email conectivity. Until now we could only verify the technical feasibility of the proponed solutions, but no their impact in the health of the patients.

Nevertheless, although we are in an early stage for getting results of impact in morbidity or mortality with the use of the computerized epidemiologic surveillance system, we are detecting a growing interest by the local public health authorities to add new vertical programs of public health to the system. They are interested in the development of a new epidemiologic surveillance model that is population-based, where, in addition to the capture of health outcomes, it allows incorporating information of other institutions, risk factors of diseases, health education programs, etc. In addition a module for the epidemiologic analysis and interpretation using geographic information systems (GIS) is being incorporated to the system in a experimental way, focused in the morbidity and mortality analysis of tuberculosis, malaria and other infectious diseases and vector-borne diseases.

Regarding the remote learning just to say that it is necessary a "change management" work in traditional procedures, parallel to the development and implantation of the systems, so the institutions could take control of the technology and see the tools as complement of their traditional continuous training procedures.

Both tools are specially designed for the improvement of diagnostic and treatment abilities of the more isolated health establishments. This one can be one of the first experiences directly addressed to underprivileged sectors of rural areas in developing countries using new information and communication technologies. We hope that the short and half term evaluations show hopeful results to continue the work.

ACKNOWLEDGMENTS

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