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Rural Telemedicine Infrastructure and Services in the Department of Cauca, Colombia

ÁLVARO RENDÓN, Ph.D.,¹ ANDRÉS MARTÍNEZ, Ph.D.,² MARÍA F. DULCEY, E.E.,¹
JOAQUÍN SEOANE, Ph.D.,³ RICHARD G. SHOEMAKER, M.D.,⁴
VALENTÍN VILLARROEL, E.E.,⁵ DIEGO M. LÓPEZ, E.E.,¹ and JAVIER SIMÓ³

ABSTRACT

The development of telemedicine programs for the public health network of the Department of Cauca, Colombia, (Department is the major political and territorial division of the country. The Department of Cauca is located on the Pacific coast in the southwest of the country.) would make it possible to satisfy many identified needs such as medical coordination, continuing education, epidemiologic surveillance, patient referral and counterreferral, and an end to the feeling of isolation among professionals who work in rural health centers. Nevertheless, geographic, economic, and social difficulties, and the lack of a telecommunication infrastructure in areas with these characteristics present a challenge of such magnitude that the majority of existing telemedicine projects in Colombia have been centered in urban or other areas which present fewer difficulties. In the municipality of Silvia, the University of Cauca has established a prototype network using the "Hispano-American Health Link" (EHAS in Spanish) program technologies, which uses very high frequency (VHF) and wireless fidelity, (WiFi, a set of standards for wireless local area networks) radio systems for the deployment of low-cost voice and data networks. Over this network information access and exchange services have been developed, in order to meet the needs identified above. The objectives were to obtain information about the development of the project's activities and their possible impact. Project telecommunication network and information services are described, and the results and conclusions of the first evaluation are presented.

INTRODUCTION

THE MUNICIPALITY OF SILVIA, in the Department of Cauca, Colombia, has identified many serious difficulties and unmet needs in its local public health care system. While tele-

medicine offers potential solutions, there are difficulties associated with its implementation that must be addressed. Located in the Central Range of the Andes at altitudes that vary between 2500 and 3800 meters, the town of Silvia has an urban population of 6600 inhabitants

¹Department of Telematics, University of Cauca, Popayán, Colombia.

²Department of Signal Theory and Communications, University Carlos III of Madrid, Madrid, Spain.

³Department of Telematic Systems Engineering, Polytechnic University of Madrid, Madrid, Spain.

⁴Department of Social Medicine and Family Health, University of Cauca, Popayán, Colombia.

⁵Ingeniería Sin Fronteras, Madrid, Spain.

(18% of the total population) and 31,400 in the rural areas (82%). Six ethnic Paez and Guambian Indian reservations, whose members comprise 80% of the population, live in this region. The remaining 20% are of Mestizo origin. The municipality suffers from high levels of unemployment. A once promising tourism industry is now adversely affected by episodic confrontations between guerrilla, paramilitary, and government forces, and there is limited access to markets for the sale of agricultural produce. In health care, only 35% of the population is affiliated with the national social security system through either contribution or subsidy. The remaining 65% lack direct protection, and are served by the local public health care system, which is the responsibility of the mayor's office. Two local, level I hospitals provide services to the population: San Carlos Hospital, located in the town, dependent on Cauca Departmental Health Direction (DDSC), and Mama Dominga Hospital on the Guambian Indian Reservation, which is administered directly by that community. The absence of a telecommunication infrastructure imposes severe difficulties on the coordination of health services and results in a feeling of social and professional isolation for many health care personnel. This is because of the state of violence in the country, the socioeconomic difficulties, and the relatively austere geographic and communication conditions.

In Colombia, there are several telemedicine projects, but few are being developed in areas as complicated as the forest and jungle regions of the Pacific Coast or the mountainous regions in the Department of Cauca. One of the most important projects was realized by Instituto del Seguro Social (Colombian Social Security Agency) in the field of teleradiology,¹ which allowed more than 360,000 digitalized x-rays to be sent to and read by radiologists. But this occurred in urban areas in several cities in the Departments of Cundinamarca and Atlántico. The telemedicine project of the National University of Colombia and the Electronic and Communications Technological Institute of Telecom (Colombian Telecommunications Company) attempted to reach jungle regions of Colombia (Department of Amazonas), but it was restricted to level I hospitals and did not link re-

mote primary health care centers.² The teleconsultation project of the University of Caldas, with regional presence, has created the "hospital network of the Department of Caldas," and has become one of the projects with a recognized projection in the country, within a relatively short period of time. Ecopetrol (Colombian Petroleum Company) provides teleconsultation and telediagnostic services, using a video/teleconferencing capability for its employees. None of these projects uses communications technology based on radios. It is believed that economic sustainability in areas where there is no fixed telecommunication network and where economic resources are scarce, the radio may provide an optimal solution. This follows the recommendation for telemedicine projects in developing countries, namely to avoid investment in technology that will not meet needs and to ensure that the infrastructure is scaled to the purposes and policies identified.³

Inspired by the technological developments and the EHAS program,⁴ The University of Cauca has developed a rural telemedicine pilot project in order to improve the efficiency of the local health care system in Silvia. Using appropriate and low-cost technologies, a strategy of a mixed network for voice and data transmission over very high fidelity (VHF) and wireless fidelity (WiFi) systems was developed. This platform permitted the development of information exchange and access services such as a computerized system for epidemiologic surveillance, distance education, patient referral and counterreferral, and teleconsultations. The objective was to provide rural health care workers with a tool for the collection, analysis, and feedback of information that would improve coordination, avoid a feeling of social and professional isolation, and maintain a system of continuing education, at a reasonable cost.

The expected results of the project were: (1) the creation of a high-speed network that permits the interconnection of the two local hospitals in the intervention area with the DDSC, as well as a low-speed voice and data network that interconnects each of the local hospitals with the rural health centers dependent on them; (2) the provision of interconnected health care establishments with a computer-

ized epidemiologic surveillance system, a program of continuing education at a distance, a controlled system to manage patient referral and counterreferral and the option of teleconsultation for difficult or uncertain diagnoses or treatment plans; and (3) an evaluation of technical and economic viability, as well as an analysis of the project's impact on the primary care services and the health of the target communities.

MATERIALS AND METHODS

Deployment of the telecommunication network

A high-speed trunk network at 2 megabits per second (Mbps) was designed and installed. This link is illustrated by a continuous line in Figure 1. The network uses a repeater (on the same mountain peak as the Guambian radio station transmitter *Namuy Wuam*) for linking the two hospitals in Silvia and the University

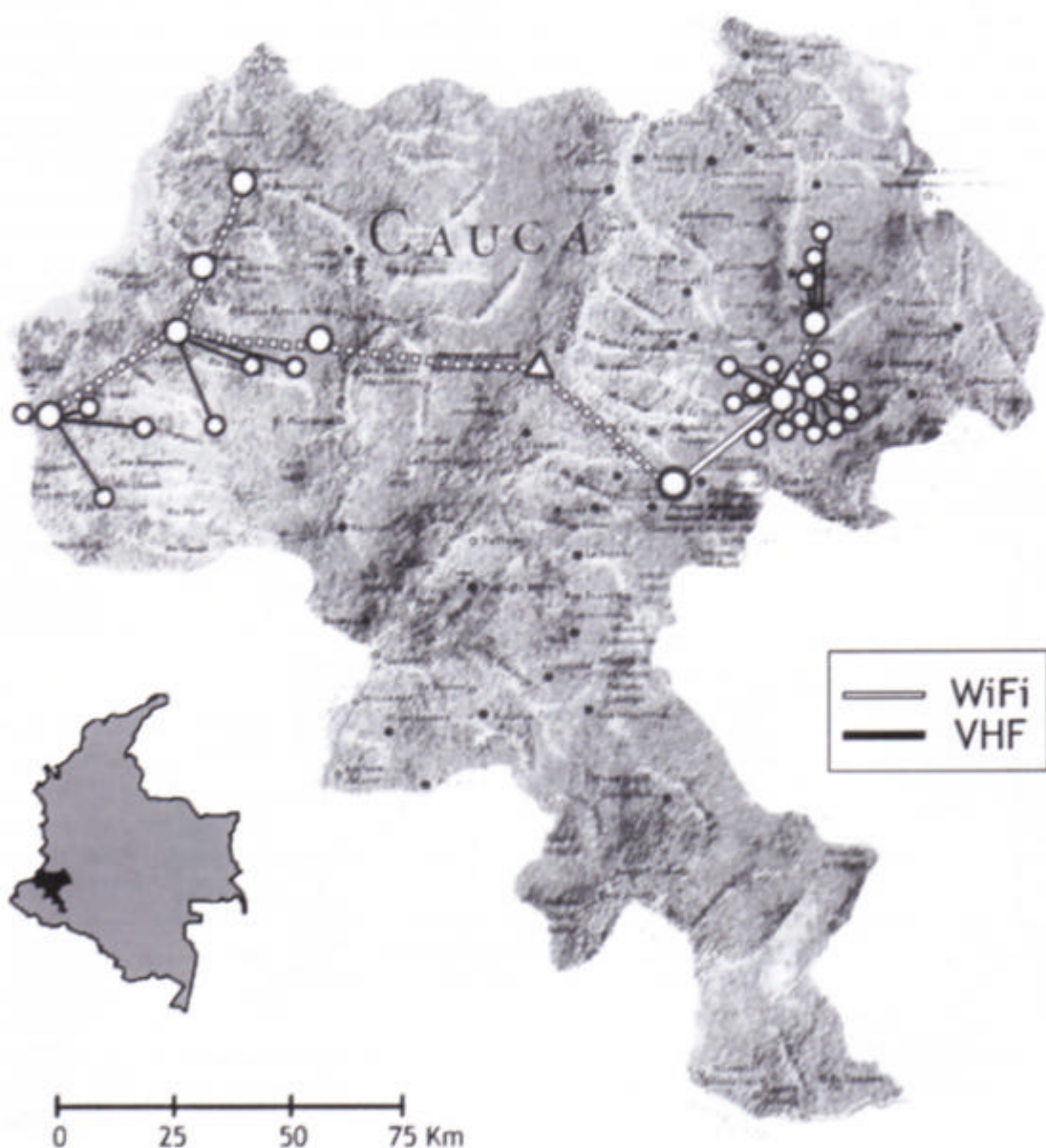


FIG. 1. Health care establishment interconnections in the municipalities of Silvia, Jambaló, Guapi, Timbiquí, and López de Micay.

of Cauca in Popayán, the capital city of Cauca. Through this network, the University provides the hospitals access to Internet services. Two more high-speed links were also designed, illustrated by discontinuous lines in Figure 1. These links provide Internet access to the Hospital of Jambaló at the north of Silvia, and to the municipalities of Guapi, Timbiquí, and López de Micay in the forest and jungle areas of the Pacific Coast in the Department of Cauca. The WiFi network utilizes a repeater on Mt. Santana, located in the western Andean Range, in order to connect the University of Cauca with the health care center in the indigenous community of Agua Clarita (in the jungle, 53 km from the repeater) and the Hospital Santa Bárbara in Timbiquí (on the coast, 88 km from the repeater). The latter will also serve as the repeater to link the Hospital San Francisco of Assisi in the city of Guapi, 33 km to the south, and the health care centers in Puerto Saija, 12 km away, and Nonanamito, 29 km to the north.

The high-speed network is the backbone for connecting the health care centers (HCC). Each HCC is connected to its hospital through a

packet radio data transmission link over VHF (9600 bps) as illustrated in Figure 1. The set of HCC depending on a hospital makes up what we call a "VHF micronetwork" (Fig. 2). There are 9 HCC dependent on the San Carlos Hospital (Fig. 4), 7 on the Mama Dominga Hospital (see the Cacique HCC in Fig. 3), 3 on the Santa Bárbara Hospital, and 4 on the San Francisco of Assisi Hospital. Of these 26 HCC, 4 have been installed and are operational in the pilot project in Silvia. Fifteen others are scheduled for installation in Jambaló and Silvia during May and June of 2004, and 7 more are planned for installation at the end of 2004 on the Pacific Coast.

Each HCC is outfitted with a personal computer, a point matrix printer, a Tigertronics (Grants Pass, OR) BP96-A radio-modem and a Motorola (Schaumburg, IL) PRO 3100 VHF radio. All the personal computers were installed with Linux Debian Woody (www.debian.org), the KDE 3.1.4 graphical desktop environment (www.kde.org), OpenOffice 1.10 utilities (www.openoffice.org), the Mozilla 1.0 browser (www.mozilla.org), and the Linux utilities to support for the AX.25 packet radio protocol.

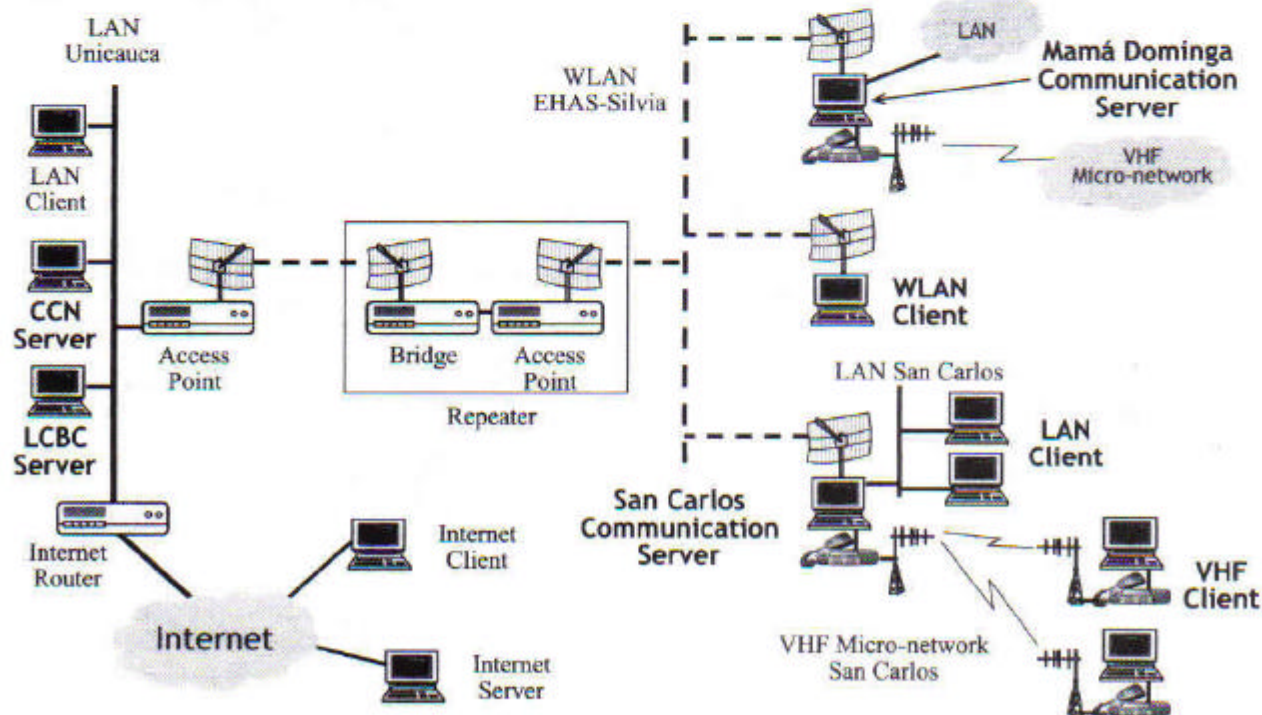


FIG. 2. Topology of the wireless fidelity-very high fidelity (WiFi-VHF) mixed network of EHAS in the Department of Cauca.

A communications server was installed in the hospitals and some of the health centers. This system consists of a personal computer equipped with an 11 Mbps wireless local area network (WLAN) card for the WiFi link, a radio-modem, and a VHF radio for the VHF micronetwork connection, and a network card for the local intranet. The computer has Linux Debian Woody installed and enhanced for AX.25 and WiFi, Sendmail (Linux e-mail server utility) for the management of electronic mail, and BIND (Berkeley Internet Name Domain) as Name Server (a system that stores information about host names and domain names on the Internet). Each establishment also has a computer client in its intranet, configured with Linux Debian, KDE, OpenOffice, and Mozilla.

Parallel to the equipment installations in the pilot project, research and development tasks for WiFi use with the intention of optimizing the technologies utilized in future network installations were conducted. EHAS had some experience in the deployment of wide-band links with IEEE 802.11b technology to a distance of 40 km. The links now planned on the Pacific Coast are up to 90 km. It is not possible to mount shorter spans because of the terrain. This represents a serious challenge. Indeed, we are not aware of any place in the world where permanent installations use this technology at such great distances. Its application here would mean bringing voice and data with a wide-band and at a low cost to a region that lacks telecommunication access. A new routing *ad hoc* wireless system with an autonomous solar power generator and quality of service (QOS) are being investigated and developed. These systems will permit the rapid and easy deployment of wide-band networks in order to switch data and voice without affecting vocal communications in situations of heavy network traffic transferring data. Additionally, by incorporating self-configuration and remote administration mechanisms which will enable less-skilled personnel to deploy networks and carry out routine maintenance, we hope to improve quality, reduce long term costs and thereby increase sustainability.

Services of exchange and access to information

According to studies carried out by EHAS in several Latin American countries,⁵ rural health care personnel need the following information access and exchange services:

Epidemiologic surveillance: There are many difficulties associated with the collection, transmission, processing, visualization, and feedback of epidemiologic information. Frequently, epidemiologic information does not get transmitted, arrives late, or with erroneous data, which in many cases, makes it difficult or impossible to make informed decisions or mobilize rapid interventions.

The Department of Telematics of the University of Cauca has developed a centralized information system for the distribution of forms (based on the Extensible Markup Language, XML) through the EHAS network. These forms are sent to HCC for health care personnel to fill them out in order to satisfy the requirements of the national epidemiological surveillance system (Sistema Nacional de Vigilancia en Salud Pública, SIVIGILA) as well as the vertical programs* (maternal and child health, tuberculosis, hypertension, etc.). The electronically collected data are transmitted through the wireless links to the hospitals, where automatic processing and visualization of the information is performed. Consequently, the information is fed back to the rural HCC in monthly bulletins.

Continuing education: The Polytechnic University of Madrid and the Carlos III University of Madrid developed a distance education system with four major components: course editor, course transformers, virtual learning environment, and unplugged client. This system complies with the requirements of intermittent connection of rural HCC in the EHAS network. HCC do not have permanent Internet connections so data transfer is only possible by electronic mail.

*Public health programs devoted to deal with specific problems.

The XML-based course editor has a highly useable interface. Courses can incorporate text, static and dynamic images, tables, self-evaluations, references, and examinations. The transformers allow course conversion from XML to the format required for diverse distribution. Hyper-Text Markup Language (HTML) is used for electronic mail. Portable Document Format (PDF) is used for printed distribution as a book. Both formats can be used for conveying the course to a web server or a CD.

The virtual learning environment offers tools for online learning and student activity tracking, such as forums, access to learning resources, etc. At HCC, the unplugged client is periodically synchronized with this environment by using electronic mail. In this way, the physician, nurse, or other health care worker at HCC make use of a learning environment as complete as those online, even though he/she finds himself in an isolated health care establishment, with the sole connection being electronic mail by radio.

Patient referral and counterreferral: The referral of patients from rural health centers to hospitals in the capital city is always somewhat complicated for the physician as well as the patient. The introduction of a referral system for patients with appointments (obtained by e-mail), and the prior mailing of a summary of their clinical histories, would facilitate the effectiveness of care by specialists. Patient follow-up would improve markedly with counterreferral support, that is, if the rural physician received by e-mail the specialists' reports of laboratory tests, procedures, therapies, recommendations, etc.

Consultations: The possibility of obtaining a second opinion from a specialist in cases difficult to diagnose or manage helps to reduce the number of elective and emergency referrals, as well as cost and inconvenience to patients and their families, as was demonstrated in a pilot study in Peru.⁶ In the case of emergency referrals, the availability of voice communication systems (VHF radio or voice-over IP in WiFi links) connecting the health care establishments at different levels, allows for a more rapid and efficient use of available transporta-

tion in rural areas, substantially reducing the delay time for patient transfer.

Short-term study of feasibility and impact

The intervention presented here is governed by a basic principle, namely to serve the interests and needs of the affected populations. This is a requisite for working with indigenous communities in Cauca, which have achieved significant levels of autonomous organization and strategies to preserve their ancestral culture. For this reason, all the decisions, from the telecommunication network design to the content of information services, were made with the active participation of the community's health care personnel, designated representatives or tribal authorities.

Consistent with this principle, the project's methodology for working with rural health care personnel and communities is Participatory Action Research (PAR).⁷ One of the fundamental characteristics of PAR is the high degree of participation by the project beneficiaries in all the phases of its execution. They join the project personnel to form a single working team in order to decide on specific actions to pursue, to learn about project results and help elaborate on the conclusions reached. This results in a continuous evaluation and adjustment of project development. At the same time, it establishes the bases for achieving one of the key objectives of the intervention and its sustainability, the integration of the EHAS services with the procedures and programs of the public health system.

The PAR methodology has been used to develop a community-wide epidemiologic surveillance system, which focuses on the social and cultural determinants of disease prevalence. Furthermore, workshops, follow-up meetings and other mechanisms used by PAR provide valuable qualitative information for the conduct and evaluation of the project.

In addition, the EHAS program utilizes surveys in order to evaluate the evolution and impact of actions at different times during its development. A first short-term evaluation has been carried out (at 4 months of functioning) in the six health care establishments of the pilot project: three in the municipality of Silvia



FIG. 3. Cacique Health Care Center on the Guambian Indian Reservation (Silvia).

(San Carlos, Usenda, and Pitayó) and three on the Guambian Indian Reservation (Mama Dominga, Cacique, and La Campana).

RESULTS

The telecommunication equipment has been installed in the six health care establishments

of the pilot project. The services provided included continuing education and consultations by e-mail, radio, and chat. The epidemiologic surveillance system is not fully operational but a first epidemiologic bulletin has been sent. The implementation of the patient referral and counterreferral support procedures has been postponed until the other services are consolidated.



FIG. 4. San Carlos Hospital.

Because of the relatively short period of system deployment (4 months), the short-term evaluation survey was applied more as an instrument of project control and follow-up than as an indicator of impact. The sample was small. Hence, the evaluation data obtained by quantitative methods was complemented with personal interviews in an attempt to validate the results. Five questionnaire responses were obtained from the eight health care workers participating in the pilot project.

The assessment of the computer and radio availability was variable. But 60% of the respondents declared that e-mail worked a "few times." Even so, all of the respondents reported that they had used the system at least twice per week. Eighty percent requested more training in the use of e-mail and office programs, and all respondents requested more training in equipment operation and troubleshooting. There was unanimity in appreciating the usefulness of computers and e-mail in supporting their work. Sixty percent prefer the radio to communicate locally (only one respondent prefers e-mail). Sixty percent reported that queries about the functioning of their equipment were directed to project personnel, and only 20% were directed to their colleagues working in other health centers in the network. Nevertheless, in spite of these initial difficulties, 60% agreed with increasing project services and coverage (the other 40% did not respond to the question).

With respect to PAR mechanisms, six workshops have been performed to train community members and health care workers in the methods to design the epidemiologic surveillance system. The participants concluded, by consensus, that the continual loss of traditional cultural values is the principal factor associated with adverse events affecting maternal and child health, which was used as an example. We have also begun the first continuing education course on Health and Disease. Its objective is to elaborate on the multiple and varied concepts of health, illness and disease in the ethnically diverse population of Silvia. Two course modules have been developed, and one forum and one evaluation exercise have been completed. Almost all of the system users participated in the forum and evaluation. None-

theless, they had to receive constant reminders, encouragement, and prodding by radio. Consequently, the few course activities to date have taken a great deal longer than originally planned. We also have sent an epidemiologic bulletin reviewing an epidemic of yellow fever, occurred earlier in 2004 on the Colombian Atlantic Coast.

Perhaps the major achievement of the project until now is having reached a critical point in terms of its acceptance by the rural health care workers and administrative personnel. In the initial phase, the initiative for developing the project was taken by project personnel themselves. Now, the initiative is being shared with health care personnel, who make suggestions and propose new activities. They have begun to appreciate the benefits of the EHAS services and realize that they need more training. On their part, the hospital administrators, who initially had assumed an expectant attitude, have adopted a more active role by showing strong interest in articulating the continuing education courses and other project services and activities with the hospitals and HCC programs. At the same time, the hospital technicians, after having received a training course in equipment maintenance and troubleshooting, now demonstrate more competence in dealing with adverse events that occur in the network.

Also, hospital administrators in the towns of Rosas, Corinto, and Santander de Quilichao, located in the Department of Cauca, have requested the installation of the EHAS systems and services in their municipalities. Furthermore, the use of the WiFi-VHF network for interventions in other sectors such as education (project E-LANE financed by the European @LIS Program) and agricultural production (Agroindustrial Community Telecenter financed by Colciencias, the national science and technology agency), has also been requested.

DISCUSSION

The telecommunication network has not been very stable as a consequence of several factors, including equipment configuration problems caused by the lack of user practical

experience and damage caused by electrical discharge. The up time of the system has been adversely affected because hospital technical personnel have not assumed their new responsibilities for the maintenance and troubleshooting of the equipment. With the expansion of the network, hospital administrators will assign labor for system maintenance.

One of the most serious difficulties we have faced was the lack of experience and knowledge in the use of information and communication technologies on the part of the health care workers. This was foreseen, and one of the earliest project activities was to train the health care personnel in the use of EHAS equipment and services. However, acquiring confidence and skill in the management of the equipment and applications, and incorporating them into daily work routines, is a process that requires a great deal of time, dedication and patience. Personnel have still not become accustomed to using e-mail and have limited themselves to activities related to distance courses and bulletins. On the other hand, the radio has been used with much more regularity, mainly because the majority has previously had first-hand experience with it. However, communication with project personnel has been limited to the coordination of programmed activities and the use of equipment rather than medical queries. This may be because of the hierarchical structure of the local health care system. Health care technicians and nursing assistants can make medical decisions only if they are authorized by physicians at the local hospital.

Future plans

With the installation of equipment in 28 additional health care establishments, which will result in 5 municipal, health micronetworks (Silvia, Jambaló, Guapi, Timbiquí, and López de Micay) it will be possible to evaluate various aspects of the impact of the project. The decision to use low-cost wireless technologies is showing positive results in Colombia as well as in other countries with similar, ongoing EHAS projects. We believe it is the most ap-

propriate alternative from the point of view of project sustainability.

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Address reprint requests to:

Álvaro Rendón
Departamento de Telenática
FIET
Campus de Tulcán
Universidad del Cauca
Popayán
Colombia

E-mail: arendon@unicauca.edu.co