EHAS Program: Rural Telemedicine Systems for Primary Healthcare in Developing Countries

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Abstract

The Biomedical Engineering and Telemedicine Group of the Technical University of Madrid (GBT-UPM in Spanish) and the non-governmental organization Engineering Without Frontiers (ISF in Spanish) are leading the "Hispano-American Health Link" program (EHAS in Spanish), to develop low-cost telecommunication systems and information services specially designed for rural primary healthcare personnel from isolated areas in developing countries. The EHAS program has five lines of action: 1) Research on the communication and information needs of rural health personnel in developing countries, 2) R&D on voice and data communication systems designed according to conditions of rural areas, 3) R&D on information services systems suited to the needs of health personnel, 4) Deployment of those services and systems through pilot projects, and 5) Evaluation of the impact of these telemedicine systems on health services. This paper presents the results of each line of work, with emphasis on the pilot scheme deployed in 39 rural sites of the Alto Amazonas province, in the center of the Peruvian Amazon region.

1. Introduction

From the beginning of Telemedicine one of its greatest promises was helping isolated or scattered population to gain access to health services [1]. Telemedicine is proving to be a good tool in enabling access to knowledge and information exchange, showing the possibilities of bringing good quality healthcare to isolated communities in industrialized countries [2]. Telemedicine could also be used (and must be used) to deliver healthcare to poor areas in countries with scarce infrastructure or even in developing countries [3], [4].

There is no doubt that information and communication technologies have tremendous potential for improving healthcare. Nevertheless, we have to bear in mind that in the rural areas of many developing countries, telephone networks and computers are scarce (Figure 1), especially in the health sector [5].

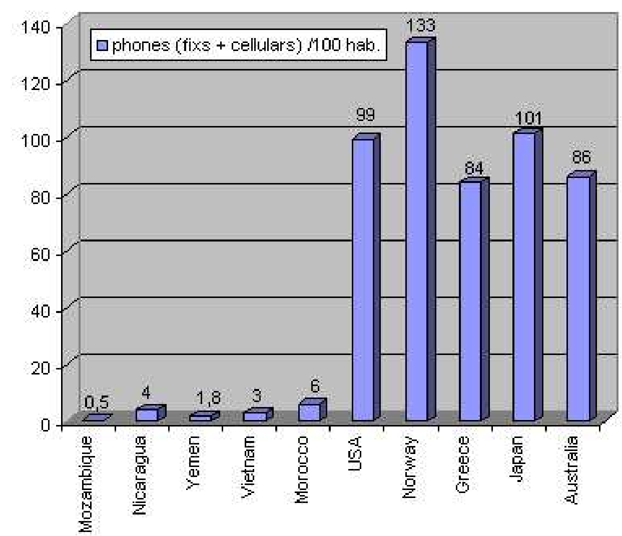

Figure 1.- Number of telephones (fixed and cellular) per 100 inhabitants.

Another barrier to the implementation of telemedicine in rural areas of developing countries is (Figure 22) the limited access to electricity [6].

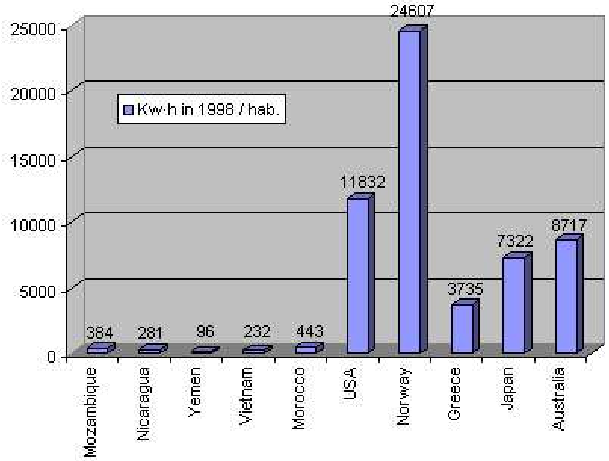

Figure 2.- Electricity consumption per capita.

Another important factor is the deficient transportation infrastructure (Figure 3) resulting in a lack of appropriate maintenance and control systems, limited ability to afford expensive telecommunication infrastructure and traffic, and poorly trained health personnel. Owing to these restrictions, the rural populations of developing countries (a highly under-attended group as we shall see) are far from enjoying the advantages of the so-called "Global Information Society". Information and communication technologies and services can improve the work conditions of isolated health staff only if those technologies are selected, developed, adapted, and carefully deployed to suit their real needs in their real environment [7].

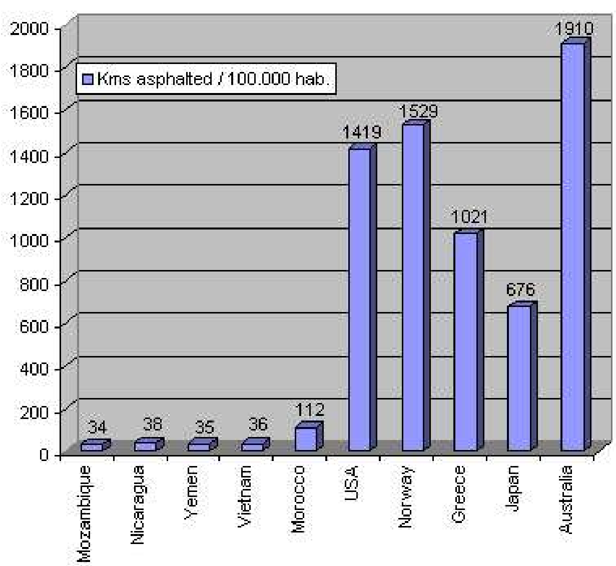

Figure 3.- Asphalted roads per 100,000 inhabitants.

These facts clearly highlight important differences between developed and developing countries that condition any telemedicine project. Moreover, the technology gap between the urban and rural zones within the developing countries themselves is a widely accepted fact. While in the main towns of developing countries most modern communication networks are accessible (ISDN; xDSL; Frame Relay, etc.), we can find many rural areas with no basic telephone network. For that reason, while the telemedicine experiences of urban areas, mostly inter-hospital projects, are very similar anywhere, the rural telemedicine projects seeking to improve the efficiency of primary care will result in quite different implementations, depending on whether we are dealing with rural areas of industrialised countries or isolated rural areas of developing countries. The needs and priorities are completely different, and most importantly, the lack of communication infrastructure and the financial limitations condition enormously both the appropriate technology and the services required. This paper supports the EHAS (Enlace Hispano Americano de Salud) initiative as a viable proposal by which to deploy telemedicine systems and services in rural areas of developing countries.

2. Rural health establishments in developing countries

Many developing countries organise primary healthcare around two types of care centres. At the most basic level, the Health Posts (HP), in other countries called surgeries, represent the way most citizens gain access to the healthcare system. At the higher level, the Health Centres (HC), also referred to as either basic polyclinics or ambulatory care centres, depending on the countries.

These HPs and HCs are usually organised in a network, the HC being the reference point for several HPs, which depend clinically and administratively on the HC. This network is what we call a "health micro-net", which is the basic unit of the primary health system. Regarding these centres, it is important to highlight the common characteristics of these centres throughout the developing countries. HPs are mainly located in small towns of no more than a thousand inhabitants, have no telephone lines, and have a poorly-endowed road network. HPs rarely have more than one health worker (two in exceptional cases), who is normally an infirmary technician or recently graduated physician with limited training. HPs depend on HCs for severe case referral, pharmaceutical deliveries, epidemiological management and coordination of the general activities within the micro-net. As a result of the widespread absence of communication systems, when health personnel need to exchange information they have to travel on foot or by land or river vehicles, taking hours or even days to do so.

HCs are above HPs in the health system hierarchy. The towns where HCs are located usually have access to the telephone network. HCs are always headed by physicians, have equipment for diagnostic tests, and sometimes cater for hospitalization. As previously explained, the HC serves as the reference establishment for several HPs.

3. Primary Care system of the Alto Amazonas province of Peru

We shall now explain in more detail the situation of the primary health establishments of the Peruvian Ministry of Health (MINSA) in the province of Alto Amazonas, Loreto region, where the first deployment experience of EHAS technologies and services is taking place. Alto Amazonas is a province with twice the surface area of Belgium and 116,200 inhabitants located in the Peruvian rain forest (Figure 4). Its capital, Yurimaguas, is divided into 11 districts. Alto Amazonas province forms a unique "health net" (according to MINSA nomenclature) with 93 health establishments: 1 provincial Hospital in Yurimaguas, 11 HCs and 81 HPs. The pilot project of the EHAS program in Peru was carried out in the southern part of the province (referred to as "Huallaga health subnet") (Figure 5) and deployed telecommunication systems in 40 establishments (the urban Hospital, 6 rural HCs and 33 rural HPs). Alto Amazonas province has only one non-asphalt road, which links the capital with the rest of the country. All other surface transport within the province has to be carried out by riverboat. Only 8 out of the 93 health establishments in the province are accessible by road.

Figure 4. Alto Amazonas province, Peru.

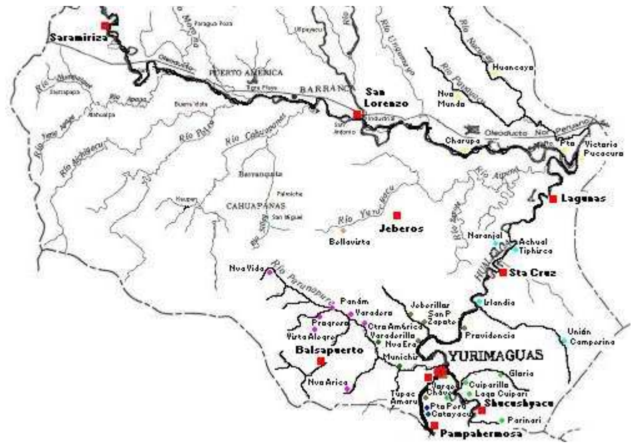

Figure 5. Map of the health network of Huallaga (Alto Amazonas province, Peru).

On 1st December 2000 we found the following scenario in Alto Amazonas:

- Only the Hospital and two other HCs (one of them in the capital) had a telephone. 71% of the establishments did not have any communication system. The remaining 29% had a HF radio or a public telephone in the town.
- Only one HP out of 32 had a physician in charge. Infirmary technicians headed the rest. The average age of physicians heading HCs was 32 years. They had 2 years' experience and only one year working in their current establishment.
- The average time taken to travel from an HP to its reference HC is about 11 hours. In case of urgent patient transfer, the mean is reduced to 8.6 hours, with a maximum of 72 hours.
- Only a quarter of the HPs had some transport vehicle (boat or speedboat) to evacuate patients.

4. Information and Communication needs in Alto Amazonas

Up to now, the EHAS program has carried out 3 studies on the information and communication needs of the rural health personnel of Latin America. In December 1997, the GBT-UPM and the Peruvian MINSA carried out a study on 41 rural health establishments randomly selected from three provinces (Morropón, Moyobamba and Islay), representing the main geographical areas of Peru: coastal desert, mountain and rain forest. This study was used to facilitate developments in technologies and services within the EHAS program. In December 1998 the same kind of study was carried out in 17 rural establishments within the province of Chinandega, Nicaragua. The objective was to compare the situation in a South American country with the situation in a Central America country, to identify potential geographical dependencies. The results were very similar. Finally, in December 2000, a third study was carried out in the Alto Amazonas province in Peru, where GBT-UPM and ISF had deployed the first field pilot project to use EHAS systems. The latter study was used to compare the initial situation with the final conditions once the pilot scheme was implemented. 32 managers of the 39 health project sites were interviewed [1]. A guided questionnaire was used to achieve an in-depth interview. The main results of the initial study were:

- The health personnel spent 28 hours a month traveling in order to send administrative and epidemiological reports. 65% of the people interviewed said that reports had been lost at some time.
- 80% declared that they had never or had hardly ever received feedback information on epidemiological topics.
- The drug acquisition system is slow. The roundtrip to get the drugs took an average of 4.3 days.
- 97% affirmed they had insufficient training.
- 50% never received a health magazine and only 1 was in the process of carrying out some kind of research.
- Workers made an average of 1.83 trips a month for coordination purposes. 75% asserted that, even traveling personally, it is difficult to make contact with the target person.
- Only one monthly trip is made to consult over doubts and it is the same trip they make for the monthly coordination meeting of the health micro-net. In the event of doubts or emergencies specific consultations are rarely made.
- The first priority for 40.5% of interviewed people was the improvement in the infrastructure of the establishment, followed closely by the acquisition of a communication system (32.4%), and the increase in personnel (16%). Nevertheless, taking only into account the personnel working in establishments without any communication system, their first priority, 43%, was to have some communication link, followed by improving the infrastructure (28%).
- About one patient transfer was made a month. Its average cost was $47. Taking into account the rest of the trips, there was a monthly average cost of $218 per worker. There were 1.45 monthly trips to the HC (taking three days each), and 1.47 monthly trips to the hospital (taking 4 days each).
- If electronic mail were used, 94.6% agreed that epidemiological surveillance would improve. With an adequate communication system, 91.7% affirmed that sharing vehicles would be more efficient. 88.9% considered decreasing the number of trips desirable.

We can conclude that the communication deficiencies seriously affect the successful coordination of activities, the sharing of information as well as the on-going education/training of the health professionals involved, thereby diminishing the efficiency of the heathcare system.

5. Restrictions imposed by the situation in Alto Amazonas

The use of a communication system seems an obvious solution for the situation described, but in order to achieve long-term viability, the situation in rural areas of developing countries has to be considered:

- There is no access to electricity in most rural villages (in rural areas of Alto Amazonas six towns have electricity, and those only 4 hours a day).
- Rural areas have limited or no public telecommunication infrastructure and they are not included in the mid-term expansion plans of the operator companies.
- Rural health establishments have limited financial resources to fund expensive infrastructure and, more importantly, the operating costs.
- Maintenance costs of any system are very high due to the long distances between establishments.
- There are few well-trained candidates for the management, maintenance and repair of computer and telecommunication systems.
- The cost of current telecommunication systems on the market is too high to become a systematic solution for all the rural areas of a country (e.g. Peruvian MINSA has more than 5,500 primary health establishments without a telecommunication system).
- No information systems suited to the real needs and capabilities of rural health personnel in Latin America are currently available on the market.

6. The EHAS proposal

Considering all the previous constraints, the EHAS program works on the research and development of appropriate telecommunication systems and telemedicine services designed to solve the needs of rural health personnel in developing countries. The partners of the program in Spain are the GBT-UPM and ISF, and their

[1] The remaining sites could not be visited due to security considerations or adverse climatic conditions.

counterparts in Peru are the Catholic University (PUCP) and the Cayetano Heredia University (UPCH). This multidisciplinary team works in two main lines of action: development and deployment of “EHAS technology”, and development and deployment of “EHAS services”.

6.1. Access system to electronic mail through VHF radio

The Biomedical Engineering and Telemedicine Group of the UPM and the Electronic and Electricity Section of the PUCP centered their work on developing an access system to electronic mail for towns without a telephone. The developed system’s main feature was: low infrastructure cost and especially low operating cost. The rest of the specifications are:

- VHF transceivers are used for voice and data (e-mail) communications within a health micro-net. This system has no operating cost.
- HPs are endowed with VHF transceiver, laptop, lighting system, and solar powered system with a minimum of five days' autonomy. (Figure 6 and Figure 7).
- The low consumption e-mail server (located at the HC) stores the email messages of the health micro-net and forwards them to the Internet through five telephone calls every day (Figure 8) optimizing telephone costs, which are shared by all the sites belonging to the micro-net. In order to simplify the network topology, the Peruvian government collaborated with the project by installing 7 telephone lines.
- Server main power is provided through a battery charger (Figure 8 and Figure 9), taking advantage of the 4 hours of electricity in the capital district and optimizing the battery load.
- A central server in Lima (permanently connected to the Internet) is the connection between the EHAS network and the Internet. When an e-mail comes from the Internet, the central server stores it temporally until the following telephone connection with the server at the HC. To increase the robustness of the whole system, a second server, located at the MINSA headquarters, is used.

Figure 6. Infirmary technician using the VHF system for voice and data (e-mail) communication.

Figure 7. Solar modules and communication tower in the HP of Lago Cuipari.

Figure 8. Server and battery loader in the HC of Shucushyacu

Figure 9. Battery pack in the HC of Shucushyacu.

To be able to use the traditional e-mail protocols (POP-3 and SMTP) and in order to use standard e-mail software clients, an open-source based application has been designed. This software is a local proxy of the server services, so that the e-mail clients must be configured as having local servers. The proxy multiplexes the connections, compresses and encrypts them, and tunnels them through the AX.25 connection[2]. Using 9,600 bps modems and a standard 12.5 kHz channel, it is capable of transferring e-mail messages at an average rate of 17 Kbps of real data.

The server at the HC is a robust, compact and low consumption embedded computer with hard disk, telephone and radio modems, Ethernet, VHF transceiver, and control circuits. It has neither keyboard nor screen and works with a Linux based operating system (GNU/Debian distribution). Any number of local computers can be connected to it through an Ethernet network, and other remote ones by radio links.

This server has a system to orderly shut down services and the hard disk when an imminent power failure is detected, automatically rebooting all the system when energy returns. Even so, to prevent possible uncontrolled failures, a transactional files system has been installed (ReiserFS).

In addition to the standard e-mail services (POP-3 and SMTP), a complementary program to that used in the clients' is running in the server, demultiplexing, decrypting and decompressing the radio connections. E-mail exchange with the outside through the telephone line uses the UUCP protocol, appropriate for intermittent connections. It uses the TCP transport through an Internet Service Provider at the cost of a local phone call.

The Linux kernel within the server has been modified to allow Demand Assigned Multiple Access (DAMA) instead of CSMA, used by standard AX.25. Thanks to that, each station does not need to see the others, allowing smaller towers and less power, reducing the costs of the whole system.

[2] AX.25 is a data communication protocol designed for semi-duplex radio communications .

Special attention has been paid to maintenance through local security backups for all hard disks and a remote maintenance system to access all the computers by radio links.

6.2. Telemedicine services for rural health personnel

The Alexander Von Humbolt Institute of Tropical Medicine from the UPCH works along with ISF in the development and deployment of services centered on the needs detected: distance training and remote access to health information. Services that have been structured in three categories of "EHAS services":

- **Distance training.** Based on an education constructivist model[3], and taking into account the principal training deficiencies of health personnel, we have developed twelve eight-credit courses, centred on the prevalent diseases of rural areas: childhood and maternal diarrhoea, infectious diseases, nutrition, etc. Courses, sent through e-mail, are developed in HTML with JavaScript to allow offline interaction with the trainees. They also have a system for self-examination and remote assessment. Other complementary training units are also provided, such as "the question of the day": a clinically focused question whose answer is provided the following day.

- **Electronic publications**. "Sanicho" magazine is edited by UPCH to provide an informal forum for the Alto Amazonas health personnel. It includes relevant news and events to reduce the feeling of isolation experienced by the rural health professionals.

- **Access to experts and health information**. This kind of service allows a mediated access to remote data bases and magazines related to health. The EHAS program uses the idea of "information access facilitators". Health personnel send an e-mail to EHAS requesting information, documents or magazines. Facilitators look for material in local and remote databases, in magazines or from experts at the UPCH. Finally, they prepare the information to be sent back to rural personnel via e-mail.

7. The first EHAS pilot experience in the field

The first pilot experience has taken place in the health network of Huallaga in Alto Amazonas, Peru. 39 EHAS telecommunication systems have been deployed. It

[3] This model assumes that the education program will be successful only if it deals with contents that can be integrated in the daily work.

consists of 7 e-mail servers and 32 client systems. There is one server in the provincial Hospital at Yurimaguas and six in the HCs of Shucushyacu, Lagunas, Santa Cruz, Pampahermosa, Jeberos and Balsapuerto. Clients are distributed over these seven health micro-nets as follows: 8 depending on Yurimaguas, 5 on Shucushyacu, 7 on Balsapuerto, 5 on Lagunas, 4 on Sta. Cruz, 2 on Pampahermosa and 1 on Jeberos.

The network came into operation in September 2001 and two impact evaluations were programmed at medium and long term (9 and 24 months respectively). These studies are centered on measuring the impact of EHAS systems (technology and services) on the health of the community, as well as the health personnel and health system. The evaluation was done through four main lines [8]: the impact on the health of patients, the impact on the health attention process, the economic impact on the various participants and the impact on the accessibility to a quality health service.

8. Impact of the pilot project (medium term)

Starting in May 2002 the technical feasibility was evaluated by means of 81 precisely defined indicators. Relevant information was compiled by documental review, direct observation, focus groups and, most importantly, questionnaire-driven interviews of the 32 managers of the 39 sites in the Alto Amazonas.

We present the main results grouped into four categories: improvement in urgent evacuation of patients, improvement in diagnosis and treatment capacity, improvement in epidemiological surveillance, and cost-benefit study.

- **Improvement in emergency evacuation of patients.** The first and main impact was produced in this area. In 9 months 237 urgent evacuations were carried out in the 39 establishments covered in the project. In 100% of the evacuations the communication system was used to communicate the patients' evacuation in order to prepare their reception, hitherto impossible to achieve. In 64% of the cases the communication system enabled the use of vehicles from other establishments, reducing the mean time employed for evacuation from 8.61 hours to 5.17 hours (60% reduction). The use of the communication system has been crucial in saving 60 patients' lives (25.3% of the cases).
- **Improvement in diagnosis and treatment capacity.** At present, 93.3% of the health staff covered by the project consider that it is easy and fast to make consultations. Before the project, 93.8% of the people thought it was impossible or very difficult. There have been 391 diagnosis-related questions (10.06 per establishment) and 254 about treatment (6.52 per establishment). 96.7% of those questions were satisfactorily answered. In 90% of the cases, questions were asked while the patient was in the establishment. In most of the cases, questions are asked in real time over the radio, instead of using e-mail. The EHAS system has been useful for distance training; 5 courses have been imparted (malaria, dengue, tuberculosis, breast breeding and first aid) and the participants evaluated them with a score of 16.95 / 20. 95.2% of interviewed people declared that the EHAS system was appropriate for training rural health personnel.
- **Improvement in epidemiological surveillance.** The EHAS system has proved to be effective in improving the epidemiological surveillance system in the Balsapuerto health micro-net (one of the most isolated areas in Alto Amazonas), by reducing to a quarter the number of trips made to send reports. In 60% of the cases the PC has been useful in filling in reports, allowing a reduction in the monthly time devoted to preparing reports from 20 hours to 13 hours (35% reduction). Malaria detection time was reduced by half.
- **Cost-benefit study.** The infrastructure and set up costs per establishment come to US$ 4,195, and the estimated cost of the telephone bill, the system's maintenance and repair is US$ 704 for the 39 establishments. The total cost of the system will be recovered by the savings generated in 2.5 years (Figure 10). In this forecast, we are only considering the savings on travel (US$ 1,718 monthly) and on patient evacuation (US$ 4,230 monthly). However, if we also consider the indirect benefits breakeven will be reached in 13 months. The indirect benefits include the increased productivity of health staff due to reduction in travel and office tasks, and productivity increase of patients and relatives due to the reduction in patient evacuations.

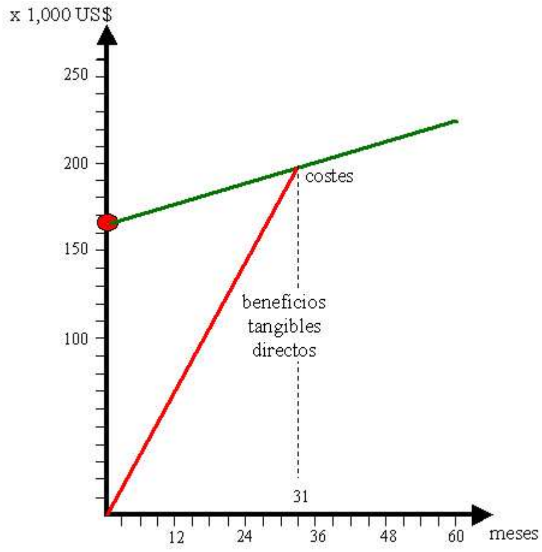

Figure 10.- Cost – benefit analysis using only the direct tangible benefits.

9. Conclusions

To the best of our knowledge, this study is the first feasibility and impact analysis of a rural telemedicine project for a developing country that includes a large sample of isolated communities (39 in the same province) using radio-based voice and data (electronic mail) communication technologies.

This project has clearly demonstrated, supported by convincing statistical evidence (in excess of 95% in all cases) that the use of technologies appropriate to the available local resources (easy to use, robust and low operating costs) solves an important part of the efficacy and efficiency problems at rural primary healthcare level. It does so by improving the speed of resolution and diagnostic capacity of the health sites, by speeding up the patient evacuation system, by enhancing the efficiency of epidemiological surveillance mechanisms, by facilitating pharmaceutical deliveries and by reducing the widespread sense of isolation, both professional and personal, felt by the rural health personnel. The feasibility and sustainability of the VHF radio communication solutions provided to implement rural telemedicine systems in developing countries has also been proved, this being a conclusion that has not been demonstrated with other satellite-based solutions. The working methodology used in the project has also confirmed the hypothesis that only with participative implementation programs, using solutions derived from the needs and constraints of the target communities, and not technology-driven, is it possible to achieve the global acceptance of all users involved: administrators, health professionals and patients, as well as the integration of a rural telemedicine system within the local health institutions.

Results obtained are intended to demonstrate to the Health Ministries of the Region that the solution proposed, systems and services, is well within the possibilities of most health rural centres. There are more powerful alternative technologies but they do not respond to the priorities of the rural sector demands and, more critically, they can never provide sustainable solutions, taking into account the limitations of the developing countries' health systems.

Companies, Public Administrations and R+D centres have to understand that the massive implantation of telemedicine and telecommunications in isolated rural areas requires a “two-way” approach. In one way, the technology has to be adequate to the user context: local economic resources, human factors and knowledge, cultural and energy considerations. In the other way, a natural interface must be provided between technology and the institutions: adequate training of the users and of the maintenance personnel, appropriate levels of motivation and tools so the administration bodies may successfully achieve the organisational changes required.

The EHAS experience demonstrates to health program funding bodies that it is possible to improve the efficiency of the isolated rural systems by means of systems and services as those we propose here, based on low complexity and low costs technology and appropriate methodologies to support the technological transfer.

10. Expansion of the EHAS Program

Following the initial results of the impact evaluation of Alto Amazonas, the EHAS program is considering five other pilot projects: two new areas in Peru (Marañón network in Loreto region and provinces of Quispicanchi and Acomayo in Cusco region); two more in Colombia (indigenous government of Guambía and Municipalities of Silvia, Jantaló, Almaguer, Piamonte, Santa Rosa and San Sebastián, all in the department of Cauca); and one more in Cuba, in the province of Guantánamo.

One of the most important results of this program is the significant North-South and South-South collaboration in the Telecommunications and Health sectors between Universities, Research Centers and a Non Governmental Organization with the aim of developing solutions for rural health systems.

The new projects will test new tools created in EHAS laboratories, such as an electronic mail system over HF radio, or a low orbit satellite mail gateway, both suited to zones with complicated orography, or a rural telemedicine system using IEEE 802.11b for carrying media-rich data.

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