PO@-SAUDE: EXPERIENCES COMBINING TELE-MEDICINE AND POWERLINE COMMUNICATION (PLC) TO IMPROVE MEDICAL SERVICES IN PORTO ALEGRE/RS/BRAZIL

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Abstract — This paper describes the project PO@-Saude, a collaborative research project among the following brazilian institutions: Federal University of Rio Grande do Sul (UFRGS), CETA/SENAI-RS - Applied Research Center, PROCEMPA - the ICT Company from the City of Porto Alegre, and CEEE - the State Electrical Energy Company), which combines Tele-Medicine and Power Line Communication Technologies in order to improve medical services delivered to low income families in public healthcare units located in Porto Alegre suburbs. The first results obtained within the scope of the project are very encouraging: absenteeism has dropped from more than 12% down to less than 3% and waiting time for ultrasound exams was reduced from 4 months to less than 4 weeks.

Index Terms — Telemedicine, Power Line Communication, Medical Training, Medical Images, Collaborative Interactivity.

INTRODUCTION

Enabled by recent advances in the areas of Information Technology, Informatics and Hardware Engineering, telemedicine has become a very interesting alternative for countries like Brazil, which has very large dimensions, heterogeneous life standards and medical infra-structure / human resources in different regions. Telemedicine applications allow an improvement of health services, increment of the population life quality, and also for remote medical training, including the residents. Based on this advance, the qualified health care of excellence medical center is extended to remote and undeserved areas with difficult access and precarious communication.

Most telemedicine applications are massive image-based (examinations obtained from ultrasound, CT, X-ray, resonance, etc), being used not just for teleconsultation, but also for a simple second opinion, repository research or remote training through the Internet. However, this strategy depends completely on the Internet bandwidth and its reliability and security.

The PO@-Saude project started within the scope of a PLC trial project developed by the project partners, which focused on performance evaluation of power line communication for transmitting different media (video, voice, ultrasound data, etc). The evaluation site was located in the area named as “Restinga”, one of the largest and poorest suburbs of Porto Alegre – capital of the Southern State in Brazil – Rio Grande do Sul, located about 30 km from Porto Alegre downtown and with a population of more than 100,000 people. One of the goals of the Po@-Saude project was to make ultrasound tests available to a larger number of pregnant women who live in Restinga as well as to reduce the high rate of absenteeism for medical tests scheduled for pregnant in healthcare facilities located in the central region of Porto Alegre. The situation was particularly worse for pregnant women with other children. Many of them could not take any obstetric ultrasound testing during their pregnancy. Since Restinga has a twice higher birth rate than the rest of the city, this situation leads to many adverse consequences, such as a higher rate of mother and child deaths or bad formation, and a higher number of hospitals beds occupied in the public hospitals.

A telemedicine system that supports real-time videos, image and voice communication, originally developed in Germany, was both adapted and combined with a PLC system. The developed system allows every power outlet in every room of Restinga's healthcare center (named “Posto Macedonia”) to be used as an Internet access point at which portable ultrasound devices connected to a laptop or computer can be plugged in and make a tele-consultation possible. Based on the results of this pilot project, the city
administration decided to start a regular, remote obstetric test service between the Macedonia healthcare outpost, in Restinga, and the Hospital Materno-Infantil Presidente Vargas located downtown Porto Alegre. The first results are very encouraging: absenteeism has dropped from more than 12% down to less than 3%; waiting time for ultrasound exams was reduced from 4 months to less than 4 weeks; and all detected malformations have been immediately taken to specialized hospitals of the city.

THE PLC SYSTEM

The data communication via the electric net grows very quickly all over the world. Designated PLC (Power Line Communication) in Europe and BPL (Broadband Power Line) in the United States, the data communication via electric power nets has become an interesting alternative that competes and/or complements the wireless communication systems, satellite and wired applications.

Being a very poor neighborhood, Restinga was not a very attractive business for telecommunication companies. The PLC Restinga Pilot Project aimed to fill this gap to attend deprived communities. The project’s goal also fits nicely with a major digital inclusion program in Brazil, whose goal is to offer to all unassisted population (or at least its great majority), independently of age, sex, income, race, ethnic origin, exceptionality level or geographical location, to receive access to tools and technological abilities necessary in the new economy. The project was motivated by the fact that the cost of PLC technology implementation and installation, using the medium voltage power lines for data transmission, is cheaper than the costs of available technologies. The project aimed to experimentally validate PLC communication as well as to identify the possibility of a sustainable business.

Taking advantage of an existing fiber optic network from the Information and Communication Technology Company of Porto Alegre (PROCEMPA) which is interlinked to the optical ring from the State Company of Electric Energy (CEEE), a PLC network was formed. It started from the CEEE substation, located in one of the extremities of the Restinga neighborhood. Illustrated on Figure 2, four different points were connected, chosen from its geographical position and lack of digital services: (1) public primary school; (2) administrative district center; (3) professional primary school; (4) health center.

Figure 1: The PLC network at a whole.

![PLC Network Diagram](image1)

Basically, the segments of communication networks via PLC can be classified in 3 areas (see Figure 1):

- **Medium voltage**: located between the electric power company substation and the low voltage transformer that serves final consumers;
- **Last mile**: power lines from low voltage transformers to consumers' residences;
- **Last inch**: use of the power lines located inside the homes for electricity distribution.

Figure 2: PLC medium tension map at Restinga.

The pilot reaches a linear extension of approximately 3.5 kilometers long, transmitting data in high-speed (45Mbps, when using equipments of first generation) via electric power net of energized medium tension of 13.8 kV. The project foresees the implantation of several services, taking maximum advantage of the communication speed provided by the system. Thus, reinforcing its complementarity with the telemedicine application.

The implementation of this net was only possible due to an optical fiber channel located at the CEEE substation (point 0 in the Figure 2). Starting from this point, the sign from the optical fiber is injected in the medium voltage network via capacitive couplers. The PLC sign goes direct trough the electrical line, with acceptable losses, in distances up to 600 meters, where regenerators modems are installed.
aiming the reconstitution of system sign. Repeating modems are also installed in these points to overlap the maneuver keys and the derivations in the medium voltage net. In the extremities special modems are used, called HE (Head End) modems, that receives the PLC signal from the medium voltage line and re-inject this signal in the electric net of low voltage (127 or 220V). The signal that arrives in the assisted points via the low voltage is extracted from the power plug using a modem for low voltage, designated as CPE. Finally, the communication system among the modems HE and CPE are point-to-point, i.e., for each modem HE only exists one CPE modem connected.

ULTRASOUND SIGNAL CAPTURE

For the telemedicine part of the Po@-Saude project, results from the T@lemed Project were used. The T@lemed project was based on a teleconsultation platform, named TeleConsult, which allows store-and-forward medical image-based telediagnosis in real-time on-line mode and also off-line.

The TeleConsult software platform is based on TeleInViVo [Kontaxakis et al., 2000], which is a telemedicine workstation used in isolated areas such as islands, rural areas and crisis situation areas. The TeleInVivo system integrates in one custom-made device composed by a portable PC with telecommunication capabilities and a light and portable 3D ultrasound station, combining low price, low weight, mobility and a wide range of non-radiating examinations. The integrated workstation used advanced techniques able to collect 3-dimentional ultrasound data of patients, which were presented on [Sakas and Hartig, 1992], [Sakas, 1993] and [Sakas et al., 2000]. For T@lemed and for this case study project, the reason to work with ultrasound data is based on its support to a very large range of applications [Ferrer-Roca et al., 2001], varying from gynaecological and abdominal scans to cardiological examinations and it is currently the only economical and affordable imaging modality available. However, the platform can deal with any other acquired DICOM images. Figure 3 shows an overview of the TeleConsult interface. Digital annotations in the medical images can be inserted by the generalist physician in remote areas and sent to the specialist physician, aiming to delineate some region of interest to be argued. The sent data can be carried through an off-line connection, where messages (images + annotations + first opinion + other crucial data to the diagnosis) are sent in a given moment (during the night, for example) and later on, in another moment, the medical specialist performs the diagnosis; or through an on-line connection. In this last way, depending on the bandwidth, data are transmitted in few seconds and collaborative discussion (annotations + chat + voice + measurements + interaction), is carried out in real-time. Figure 4 depicts the annotation interaction.

In the scope of T@lemed project, doctors from four remote cities of the Rio Grande do Sul State were connected via wired internet (512Kbps) with a specialist center (Santa Casa Hospital) in the city of Porto Alegre. Figure 5 depicts the simple network configuration.
THE PROPOSED TELEMEDICINE SYSTEM

Po@Saude initial ideas arose in meetings with the Municipal Health Department of Porto Alegre (SMS/POA), it became clear the inhabitants from Restinga had great difficulty in undergoing more sophisticated medical exams, which are made outside the neighborhood, in better equipped health centers with specialized health professionals. Most of the patients have neither enough money to pay for four to six buses nor time to spend a whole day to come to hospitals in Porto Alegre downtown, more than 30km away from Restinga. Pregnant women with other children are one of the most affected groups, because they have difficulties to find somebody to take care for their children during their absence. Because of this, a high absenteeism in obstetric exams was usual. Such ultrasound based exams during the prenatal period are very important to avoid complications that when not identified on time, may lead to the loss of the fetus and, even, to the death of the mother.

The decision was to develop a synchronous telemedicine system for routine obstetric ultrasonography exams at the Macedônia Center, under responsibility and remote real-time monitoring of specialist doctors from the Fetal Medicine Department of Presidente Vargas Maternal-Infant Hospital, located in the central region of Porto Alegre. The result, for the pregnant women community from Restinga, would be the early identification of pregnancy problems in the mother and/or in the fetus, the anticipation of the treatment and monitoring of problematic pregnancies, including the usage of therapeutic alternatives that can only be adopted early in the pregnancy. This way, a reduction in the number of fetus and mother deceases during pregnancy was aimed.

HMIPV (Presidente Vargas Maternal Infant Hospital) specialists, after evaluating the original version of the Teleconsult software, indicated the need to incorporate a transducer position on the patient's abdomen additional to the real-time video produced by the ultrasound equipment. Further, they required the possibility of VoIP communication synchronized with ultrasound video.

Based on this, the system specification was made together with the medical area, and its foundations are to obtain real time with:

- Remote pointer, so that the doctor can show details to the patient and the resident physician (who is with the patient). The local doctor uses its mouse inside the ultrasound area, and the mouse movements are send to the remote place, showing specific areas which the doctor wants more attention;
- Video also showing the hand position of the remote resident physician, which shows the transducer position on the patient's abdomen.

Figure 6: Schematic of the developed solution

Figure 6 shows a schematic of the developed solution. At both ends, there is audio coding and transmission. In the remote module, the system receives the video signal from the ultrasound and the hand position of the attendant, composing both videos on the same screen. The attendant hand is in PIP (Picture in Picture) form, generating a small resolution video. This signal is coded in MPEG-4 and transmitted live, being received by the doctor, who analyses it and communicates by audio and through the remote pointer, giving instructions to the patient and the attendant.

A support software called TeleConsult [Medcom, 08] was used to capture the ultrasound signal. Besides capturing the ultrasound images and showing them at the computer screen, it allows freezing selected images and storing them in the DICOM format. The user might, then, open these DICOM files and edit them graphically and textually. When the edited file is saved, the program saves, also in DICOM, the graphic and textual editing in the same file. To the real-time application, it was not necessary to store the images. It was only performed if the doctor asked so, for future analysis. The software allows also making calibrations with the ultrasound and measuring determined areas, as the fetus' head diameter, femoral bone size, and so on. This is important to the doctor to get the fetus size, comparing to standards and finding growing anomalies.
With the patient, there must be the presence of an accredited physician, because according to Brazilian laws (ANVISA - National Agency of Health Watch), only physician can perform ultrasound exams, since the image selection and the report are generated at the time. This is not the case, for example, of x-ray of mammography exams, where a nursing technician is authorized to capture the image and the specialist doctor (remote or local) analyses it later and makes the report.

So, in the remote place, there is a non-specialist physician, in this study-case, a 4th year resident, who performs the exam at the patient. At the main hospital (HMIPV, in this case), is the specialist doctor, responsible for the report.

The following matter may appear: in this case, two doctors are working instead of one, so why not take the specialist doctor to the patient? The reasons are:

- The cost of the specialist doctor is high, and it would be a waste of time to move him through the city to attend in distant centers;
- The number of obstetrics, fetus medicine and ultrasound exams specialist doctors is not big at the municipal administration. So, it becomes more efficient to keep a specialist in a central place, able to perform more remote exams. Each exam takes from 20 to 30 minutes. While the non-specialist physician prepares the patient and starts the exam, the specialist might be discussing with another doctor a second (or third) exam, made almost in parallel.
- Many times, the specialist doctor does not accept to go to far away communities, because some of them have public safety issues.

The system internal structure, placed at the health center, is shown on Figure 7, where its different libraries can be seen, as well as the connections among them. The description of each library is presented hereafter.

- **Capture**: responsible for receiving the audio and video signals generated by external equipment, such as camera and microphone, independent from the communication interface (DV, acquisition card or USB). In the specific case of tele-ultrasonography system, the capture module received four simultaneous captures: a) the ultrasound video signal; b) the video signal showing the attendant’s hand position; c) the attendant audio; d) the video monitor image;
- **Audio and video coding**: responsible for compressing the audio and video streams, captured for later transmission. The generic interface allows working with different coding algorithms. The available video coding algorithms are MPEG-2, MPEG-4 e H.264 protocols, and de audio coders are the G.711 e AAC (Advanced Audio Coding) protocols. In this case, de decoding was compressing the audio and image from the video monitor;
- **Network**: implements the point-to-point communication between the local and the remote locations.
- **Audio and pointer decoder**: decodes the audio that comes from the main hospital, as well as the pointer signal controlled by the doctor;
- **View**: shows the following at the video monitor: a) small-sized image of the attendant hand position; b) large-sized ultrasound image; c) remote pointer image, controlled by the doctor. Besides that, it decodes the doctor’s audio and presents it on the speakers.

The block diagram of the system placed at the main hospital is complementary to this one, presented at Figure 8. The main differences from the remote one are that the system codes only audio and pointer. Besides that, it decodes the remote audio and video, presenting them on the computer screen.
PRELIMINARY RESULTS

To illustrate PO@ Saude, only to demonstrate the project conceptual meaning, the Figure 9 depict the first prototype using a low-cost portable ultrasound and a screen sharing application running on the background of the developed ultrasound viewer. Different from T@lemed, here we used common sharing software to perform the initial tests regarding the real-time acquisition and a web-camera window for the transducer position viewer. As expected, the screen sharing consumed a high bandwidth of dedicated 1.2 Mbps for screen transmitting and VOIP. However, the images updated were performed in real-time allowing basic training, and the exams were capable to identify the pulsation , like, for example, the fetus hearts pulse, which is very important to recognize if the fetus is sleeping or dead in the case of motionless.

![Image of a portable ultrasound and screen sharing application](a)

![Image of ultrasound images and transducer position](b)

Figure 9: PO@Health using a portable ultrasound (a) and a screen sharing application for the ultrasound images and transducer position (b).

This test will be useful for a future image-quality and bandwidth consume benchmark, comparing the final stream-based solution with other possibilities.

CONCLUSIONS AND FUTURE WORKS

This short paper presented the applied research for the general conception of a telemedicine system which is being developed/adapted based on ultrasound images and on PLC data communication for resident physicians practical distance training. The study case scenario is on the Restinga remote district of Porto Alegre city, where there is a PLC-based network implementation going on. We believe that the use of PLC as the channel for data transferring will be feasible and bring great capillarity for telemedicine services, which deal with large data.

Performance measurements on the PLC network at Restinga are also a current work, verifying in loco that the first generation of equipments will allow us to reach up to 45Mbps in an optimistic situation. We also intend to update some PLC equipments to the second generation, allowing theoretically up to 200Mbps and look over the performance of a mixed network composed by first and second generation equipments.

Further studies on PLC and telemedicine feasibility will also be performed, trying to expose it’s complementarity and thus the PLC capillarity.

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REFERENCES


