PO@HEALTH

A medical training telemedicine case study based on ultrasound images over an hybrid Power Line network

Alécio Pedro Delazari Binotto, Flávio Ávila, Carlos Eduardo Pereira

CETA - Center of Excellence in Advanced Technologies SENAI, Av. Assis Brasil 8450, Porto Alegre, Brazil
UFRGS - Federal University of Rio Grande do Sul (Informatics and Electrical Engineering Departments), Av. Bento Gonçalves 9500, Porto Alegre, Brazil
abinotto@inf.ufrgs.br, favila@ceta.senairs.org.br, cpereira@ece.ufrgs.br

Cirano Iochpe

PROCEMPA - Information and Communication Technology Company of Porto Alegre, Av.Ipiranga 1200, Porto Alegre, Brazil
UFRGS - Federal University of Rio Grande do Sul, Av. Bento Gonçalves 9500, Porto Alegre, Brazil
ciranoi@procempa.com.br

Ilias Sachpazidis, Georgios Sakas

IGD - Fraunhofer Institute for Computer Graphics, Fraunhoferstrasse 5, Darmstadt, Germany
isachpaz@igd.fhg.de,gsakas@igd.fhg.de

Abstract: The growth of fast internet, including the recent advance on using PLC (Power Line Communication) for reaching rural and remote areas in Brazil, and the state-of-the-art of image compression methods allowed rapid teleconsultations and medical training based on medical images. At the present time, one of the challenging problems in telemedicine is the real-time teleconsultation in case of emergency and for the medical training at remote regions where the internet access is precarious. In this paper, we present the kick-off of the applied project PO@Health, which merges the European-Latin American T@lemed Project (telemedicine based on ultrasound images) and the Brazilian PLC Restinga Project (communication via Power Line in a remote district). The platform used for medical teleconsultations and residents training is able to perform both on-line (in real-time) and off-line image-based teleconsultations over the Internet connection. For the ultrasound cases, the platform is being adapted to work with the DICOM medical images synchronized with the physician hand position images of the examination in order to increase the diagnosis precision. In addition, we describe the hybrid network over PLC that is being used by the telemedical platform.

1   INTRODUCTION

Actually, telemedicine is currently growing as a research topic for the 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 centres 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, ray-X, 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 communication through the electric net grows very quickly all over the world (Motorola, 2007). Designated PLC (Power Line Communication) in Europe and BPL (Broadband Power Line) in the United States, the data communication through electric power nets is

already an alternative that competes and/or complements the wireless communication systems, satellite and wired applications, like cable TVs (Opera, 2007).

Based on the telemedicine and using PLC as part of the communication channel, this paper will present the ongoing work and its preliminary results performed at the PO@Health Project, located in the capital city of Porto Alegre (Rio Grande do Sul State, Brazil) and it is organized as follows. It starts with a brief motivation and description of the medical scenario. We follow with previous work on projects in the telemedicine and PLC areas and a detailed explanation of the proposed platform (emphasizing ultrasound examinations) and the network communication. Then, we present the medical, technical, and social results achieved during the first pilot. Finally, we discuss the estimated benefits and directions of the on-going and for future work.

2 MOTIVATION

At Porto Alegre, capital city of Rio Grande Do Sul State in Brazil, the Maternal-Infantile Hospital Presidente Vargas (HPV) is a medical referral center involving pregnancy. The public hospital assists a vast part of the population in the city who lacks of specialized maternal/medical infrastructure. Most of these patients come from remote districts just for the accomplishment of routinely ultrasound examinations and for accompaniment of pregnancy evaluation.

Restinga is the poorest and the most remote district of Porto Alegre, having more than 80.000 inhabitants, with a population density of 23 inhabitants/ha, and occupying more than 20.000 homes. The growth tax between 1991 and 2004 was from 5,6% per year and the medium monthly income of the answerable for the domiciles is 3,03 minimum wages.

The district counts just with a small health center and lacking of specialist physicians and basic medical devices, including ultrasound equipment. The health center sums up an average of 300 patient transfers to HPV per month for basic ultrasound examinations, being more than the half in the field of obstetric/gynaecologic. This represents a risk for the patient since this kind of transfer involves transportation risks in bad conditions streets, traumas and other financial costs for simple exams. In addition, it overflows the HPV capacity with patients that, in the majority of the cases, could be assisted in their own district by available General

Practitioners, the residents, for example, helped by an expert doctor, using a basic structure with ultrasound and internet connection. In fact, most of the cities have a basic structure of general doctors who, very often, cannot give a final and correct diagnosis without a second medical opinion or assistance/discussion, even remotely over the internet.

Nevertheless, there was no fast internet connection structure at Restinga since the year of 2006, when a power line communication pilot project started to be implemented, offering fast internet communication in the plug-ins of four public buildings.

The next section will go in detail over two previous projects, one based in telemedicine and the other based on PLC, which are the basis for the just-started applied project PO@Health (telemedicine over PLC).

3 PREVIOUS AND PARALLEL EXPERIENCES

3.1 T@lemed

Following the telemedicine concepts, the T@lemed Project (T@lemed, 2007) was developed by the authors and was based on a teleconsultation platform, named TeleConsult, which allows a medical store-and-forward image-based telediagnosis in real-time on-line mode or either off-line.
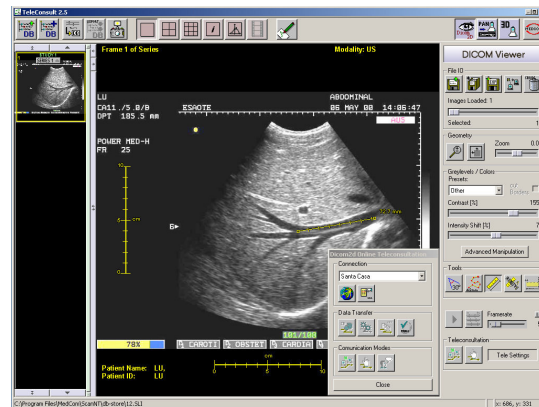

Figure 1: TeleConsult main interface.

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 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 gynaecology and abdominal scans to cardiological examinations and it is currently the only economically and practically affordable imaging modality. However, the platform can deal with any other DICOM images acquired either through the DICOM network. Figure 1 shows an overview of the TeleConsult interface.

As an example of its functionalities, digital annotations can be made by the generalist in the medical images and sent to the specialist physician, aiming to delineate some region of interest to be argued. The data sending can be carried through an off-line connection, where messages (images + annotations + first opinion + other crucial data to the diagnosis) are sent in determined moment (at night, for example) and later on, in another moment, the medical specialist performs the diagnosis or opinion; or through an on-line connection. In this last way, depending on the bandwidth, the data are transmitted in few seconds and collaborative discussion (annotations + chat + voice + measurements + interaction), is carried out in real-time. Figure 2 depicts the annotation interaction.
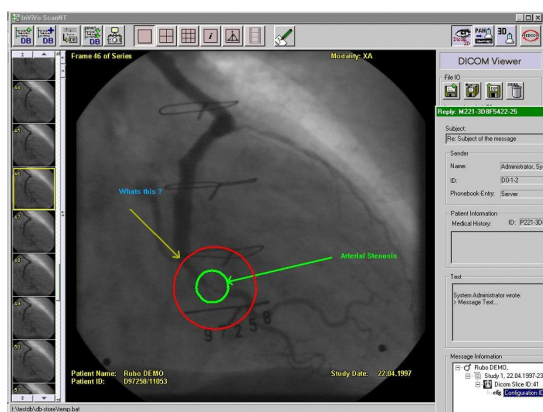

Figure 2: TeleConsult collaborative annotations.

In the scope of T@lemed, the doctors from four remote cities of the Rio Grande do Sul State were connected over wired internet (512Kbps) with the specialist center (Santa Casa Hospital) in the capital city of Porto Alegre. Figure 3 explore the simple network configuration.
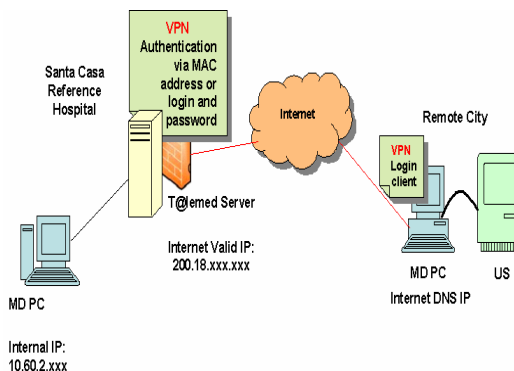

Figure 3: T@lemed network configuration.

3.2   PLC Restinga

The PLC Restinga Pilot Project, PLC network in the Restinga district, arises to supply an economical gap promoted by wire telecommunication companies, to attend deprived communities. Concerning the work of (Borges, 2005), the digital inclusion goal in Brazil is to look for the population (or at least its great majority), independently of age, sex, income, race, ethnic origin, exceptionality level or geographical location, to be able to receive access to tools, services, and necessary technological abilities in the new economy. The PLC technology implementation cost and installation, using the medium tension net for data transmission, could be cheaper than the costs of available technologies, being the sustainability and cost effectively one point of study in this on-going work performed by part of the authors from this article.
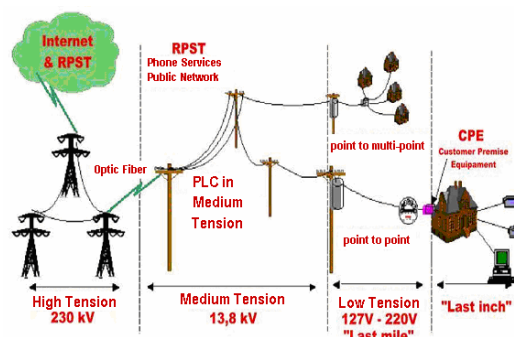

Figure 4: The PLC network at a whole.

Basically, we can classify the segments of communication networks via PLC in 3 areas (see Figure 4):

- **Medium tension**: interval between the electric power company substation and the transformer of low tension that serves the final consumers;
- **Last mile**: interval of electric net in between the transformer of low tension and the consumer's residence;
- **Last inch**: interval of electric low tension net located in the consumer's dependences.

Taking advantage of the fiber optic network from the Information and Communication Technology Company of Porto Alegre, which is interlinked to the optic ring from the State Company of Electric Energy, a PLC network was formed, beginning from the CEEE substation, located in one of the extremities of the Restinga neighborhood. Illustrated on Figure 5, four different points are connected, chosen from its geographical position and lack of digital services: (1) public primary school; (2) district administrative center; (3) professional primary school; (4) health center.

Figure 5: PLC medium tension map at Restinga.

The pilot reaches a linear extension of approximately 3.5 kilometers, transmitting data in high-speed (45Mbps, since we use the first generation of equipments) on the electric network of energized medium tension of 13.8 kV. The project foresees the implantation of several services, taking maximum advantage of the communication speed made available by the system. Thus, its complementally with the telemedicine application.

The implementation of this net was only possible due to an optic fiber channel located at the CEEE substation (point 0 in the Figure 5). Starting from this point, the sign from the optic fiber is injected in the medium tension net throughout capacitive couplers (Figure 6a). The PLC sign goes direct trough the electrical line, with acceptable losses, in distances of up to 1200 meters, where regenerators modems (Figure 6b) are installed aiming the system sign losses reconstitution. Repeating modems (Figure 6b) are also installed in these points to overlap the maneuver keys and the derivations in the medium tension net. In the extremities special modems (Figure 6c) are used, called HE (Head End), that receives the PLC signal from the medium tension line and re-inject this signal in the electric net of low tension (127V/220V). The signal that arrives in the assisted points through the low tension is extracted from the power plug using a modem for low tension (Figure 6d), designated as CPE. Finally, the communication system among the modems HE and CPE are point-to-point, i.e., for each modem HE just exists one CPE modem connected.
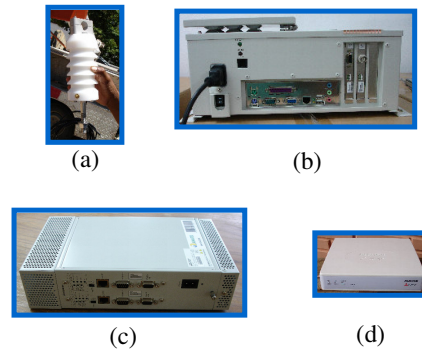

(a)   (b)

(c)   (d)

Figure 6: PLC equipments: (a) capacitive coupler; (b) regenerator and repeating modem; (c) HE modem; (d) low tension modem.

4 PO@HEALTH PROPOSED PLATFORM

The "Health at Porto Alegre" (PO@Health) Pilot Project is on its user requirements phase and has the goal to merge the experiences described on Section 3 (telemedicine over hybrid PLC network) with the foreseen significant differences bellow:

- **Ultrasound training for residents**: the focus on this pilot is on the resident physicians distance training. This means that the platform should offer an interface with fast connectivity where the expert physician is able to guide interactively the resident physician on image acquisition and thereafter on the diagnosis. The study case increases on its importance since the Brazilian law authorizes just medical physicians to operate ultrasound;
- **Interactive tele-acquisition**: as the focus is on residents, the expert doctor has to visualize the *ongoing-acquirement* of images in real-time or at least with acceptable interactivity and not allow just a store-and-forward collaborative opinion or telediagnosis;
- **Transducer location image**: ultrasound is the only medical device which produces medical images that are completely human-dependent on its acquirement. Due to that situation, the ultrasound transducer position on the patients body is a crucial information for the exam interpretation. Hence, the platform must also afford the medical images synchronized with the transducer position;
- **PLC and telemedicine economical model improvement**: the pilot will deploy an feasibility study for PLC based on telemedicine direct costs (for example, costs of exams, communication, transportation, etc) and non-direct costs (for example, psychological traumas, savings due prevention, etc);
- **Prevention control**: on the medical point of view, the pilot should also contribute on development of prevention control methods for remote regions, since they do not need to wait for the symptoms because telemedicine is a way to improve the capillarity of expert knowledge.

5 PRELIMINARY RESULTS

To illustrate PO@Health, only for demonstrating the project conceptual meaning, the Figure 7 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. As expected, the screen sharing consumed a high

bandwidth of dedicated 4 Mbps for screen transmitting and VOIP. However, the images update was not performed in real-time allowing basic training, but not capable for exams aiming the pulsation detection, 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.
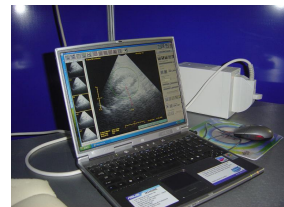
(a)
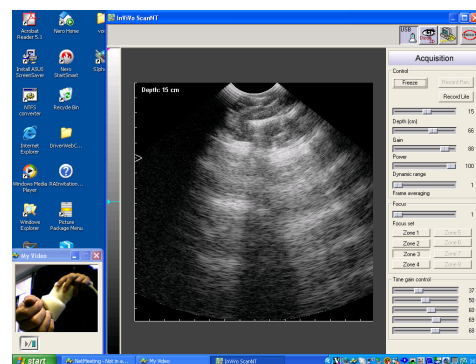
(b)

Figure 7: 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.

6 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.

As current work, we are performing the benchmark tests using a stream-based application sharing (RRD Streaming, 2007) which is a general solution to stream desktop contents to remote locations in real-time, focusing on live video, presentations, simulations, 3D visualizations, and dynamically changing scenes applications. Depending on the results, RRD Streaming will be the basis for the TeleConsult adaptation to attend the main user requirements (synchronized interactive tele-acquisition module and transducer position in real-time).

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 complementarily and thus the PLC capillarity.

ACKNOWLEDGEMENTS

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