Intelligent Management of Processes in a ICU Telemedicine System

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Abstract – This work presents a project of telemedicine applied to Intensive Care Units (ICUs). The implemented communications scheme can be adapted to patients interned in an ICU as well as to remote patients connected to the principal hospital through the communication lines. The developed system also provides maximal flexibility on the physical level, allowing ISDN, ADSL, ATM and dedicated lines. This project focuses on the acquisition of medical data, the management of the communications and the visualization and posterior analysis of the data. It also includes a series of multimedia options that facilitate the collaboration during the diagnosis: use of videoconferences following video compression protocols (H.323), collaborative whiteboard (norm T.120), visualization of graphic files related to the patient, transmission of files by means of sockets, etc.

The global system follows the IEEE MIB P-1073 standard, which it improves by including the acquisition of analog signals and to which it adds a component of intelligent monitoring using a knowledge based system (alarm check, tendencies analysis, communications control, etc.).

The system disposes of an intelligent module (rules based system developed in OPS/R2) charged with the management of the communication between the different processes, with the data transmission priorities, the bandwidth management, the management of the charge between various resources, etc.

Key words – Telemedicine, monitoring, ICU, visualization, multimedia

I. INTRODUCTION

The Intensive Care Units (ICUs) of a hospital dispose of a range of medical monitors that allow the staff to acquire and analyse a patient's physiological signals, thus obtaining a set of real-time signals and variables. These signals are shown on screen and facilitate the follow-up of the patient's actual state. Typical examples of this kind of medical devices are breathing machines, capnographs, hemodynamic monitors, etc. They all serve the same purpose, which is to help the specialized clinical staff to take decisions on diagnoses and therapies. However, it became necessary to consider both a growing number of parameters that needed to be analysed, and the progresses in information and communications technologies: a situation that led to the appearance and introduction of intelligent monitoring systems in order to help the physician with his diagnoses. Researchers opted for the supervision of an ICU patient by a bedside computer, which gathers, integrates, stores and visualizes in a clear way all the information that is forwarded by the medical devices. These systems can also be

equipped with an intelligent component that performs tasks such as the autoconfiguration of acquisition, alarm triggering, devices control, etc.

The generalization of communications networks has led to the integration of the medical systems in data networks under the supervision of a central system, following a client/server architecture. In this way, all the information that is generated by the bedside subsystems can be gathered and integrated in a single environment (central remote subsystem).

In the ICUs, the application of these new technologies generates a great amount of technical difficulties, due to the fact that there is a constant need for constantly updated information.

Within these type of systems, the IEEE MIB P-1073 standard is among the most generally accepted for the communication of medical devices connected to the patient. Basically it is a norm that describes a LAN (Local Area Network) and that follows a layer approach compatible with the ISO/OSI standard. This work presents an implementation on this standard that improves and extends it in several aspects [Figure 1]. One major extension is for instance the possibility to obtain data from analog sources by means of a data acquisition card connected to the exits of the medical monitors, whereas the original standard limits itself to the acquisition of digital signals [1].

Figure 1. Acquisition and communication architecture.

The implementation communications schedule is entirely flexible, since it is able to auto-adapt itself to the capacity of the available dataline. This allows it to be implanted on ISDN, ADSL, ATM or dedicated point-to-point lines, which is essential to include the largest part of the cases that appear on the existing communication lines in hospitalary centres.

All telemedicine systems, and concretely those in UCIs, must dispose of multimedia applications that facilitate as much as possible the collaboration with the physician during the

diagnosis. This is the case of a complete videoconferencing system (video, audio and collaborative whiteboard), the visualization of graphic archives such as X-rays, or the transmission of files with any kind of relevant digital information (e.g. clinical records), etc.

For an ICU, the information needs are a part of what we know as "hard real time"[4], since the real time medical and control information must be exchanged between client and server systems. This is due to the need to update continuously the data on vital parameters of the patient (Heart rate, Arterial Pressure, Central Veined Pressure, Intracranial Pressure, etc.) So we have equipped our telemedicine system with an intelligent module (rules based system developed in OPS/R2). This is one of the most important parts of the system, and is charged with a whole range of tasks, such as: management of the communication between the different processes, assignment and modification of the priorities of data transmission, correct distribution of the available bandwidth between the different tasks (giving higher priority to critical tasks, as opposed to the transmission of large files or the quality of videoconferencing), the management of the charge between the different resources (distribution of tasks between various computers, launch of various processes through threads, charge state of each computer, etc).

II. DESCRIPTION OF THE SYSTEM

Among the main characteristics of the project are the following:

In order to obtain the real-time acquisition and visualization of physiological signals, we have defined a number of adequate interfaces that allow the physician to work in a simple and comfortable manner. The control parameters of the signal acquisition must remain as limited as possible and be very clearly defined. It will be possible to show more than one signal at a time, so that decisions can be made based on the visualization of related physiological signals.

External communication takes place through especially implemented functions that allow the exchange of multiple information. According to the priority level of this information, the bandwidth will vary from moment to moment.

For each patient the applications located in the ICU are totally controlled by the central system, through visualization or remote control.

Both local and remote systems dispose of certain multimedia options essential to any kind of modern telemedicine system: videoconference (audio and video) and whiteboard, transfer of files of all formats and the possibility to compress them before their transmission, visualization of graphical information about the patient, etc.

Considering the forementioned options, this telemedicine project distinguishes two related subsystems to perform a correct monitoring of the patient:

- Local subsystem (client system), placed next to the patient. It is installed in a compatible computer (PC), it runs under MS-Windows, and it has the necessary hardware for videoconferences and the acquisition of data from the medical monitors connected to the patient. Its

main functions are the following: real time acquisition of analog and digital signals, local visualization and transmission of data to the central remote server, and a set of multimedia options (videoconferencing, whiteboard, file transfer, etc.) that complete the telemedicine system.

Figura 2. Main interface of the local subsystem.

- Central remote subsystem (server system). It is implemented for two different operating systems: MS-Windows 9x or NT, and Unix for a SGI 02 (XWindow) computer. Among its main functions are: the total remote control of the local subsystem (of all the patients that are connected to the system), the remote reception and visualization of signals, and a set of multimedia options similar to those implemented in the local subsystem.

Figura 3. Main interface of the central subsystem.

Both subsystems interact through a communication mechanism that is common to MS-Windows and Unix, in this case *TCP sockets*, since the communication takes place over LAN and WAN networks on the TCP/IP protocol. The information that has to be transferred between these two subsystems can be of various kinds, but it is mainly information related to real time signals. In order to reduce the bandwidth used for this transmission, we perform a previous compression with the compression algorithm without dataloss called *zlib* (RFC 1950-1952).

Information transmission inside the system requires the use of a specific channel for each kind of data. So we distinguish:

- Control information, dedicated to the transmission and reception of information related to the remote control of the local subsystem by the centralized subsystem.

- Data on the signals, transmitted to the server for each acquisition of a signals buffer in the local subsystem. More or less 70% of the generated traffic is reduced by the data compression functions of the *zlib* library.
- Compressed data on audio and video, used for videoconferencing communication. When the two systems stop communicating, their communication channel becomes available. The bandwidth that is used can be configured depending on the existing charge in the system: the transmission of signals has priority over the transmission of video images.
- Transfer of any kind of files (e.g. X-rays), which can be previously compressed with the *zlib* library functions.

Each specific task makes use of a thread, which exploits as much as possible the used CPU time by performing simultaneous tasks [Figure 4]. For instance, signals coming from the acquisition card of analog data are obtained in an exclusive thread. There also exists a thread dedicated to the reception and transmission of remote control orders or commands. A case apart is the possibility to launch a specific thread with an intelligent module (rules based system developed in OPS/R2). This module is especially relevant since it is charged with the communication management between the different processes, with data transmission priorities, bandwidth management, etc. It also manages the charge between the distinct resources (task distribution between various computers, launch of different processes through threads, charge state of each computer, etc), and it decides which system functions may be used and which not, depending on the capacity of the communication line. To this effect, it performs the processing in the local or central system according to aspects such as the information on line speed or the charge of each machine, it determines the priorities of data transmission in case of alarm, restricts the use of videoconferencing applications to lines that have sufficient capacity, etc.

Figure 4. Control processes schema.

As said before, inside the global system the assignment of priorities to the data transmission is inevitable: critical data, such as signals coming from the medical devices, have priority

over other data that are not vital, such as videoconferencing. In TCP/IP it is very difficult to regulate the transmission priorities, since there are no clear structures for the distribution of bandwidth between the enabled communication channels (open sockets). Our system regulates priorities on application level and through the use of the "Out-of-band Data" type for communication via sockets, giving so maximal priority to transmission. The videoconferencing application was developed with *VCON Development Kit* software, which uses specific OCX for each type of existing communication environment (ISDN or IP on LAN/WAN). We use H.323 on IP and H.320 on RDSI. VCON has developed *PacketAssist*TM - an architecture able to obtain Quality of Service (QoS) for interactive video on IP networks - which helps to eliminate network congestions while optimizing quality and transmission reliability.

Figure 5. Videoconference communication scheme.

III. CONCLUSIONS

The great amount of information generated by the medical monitors that supervise ICU patients, and the need to process this information as fast as possible, impose the implementation and implantation of modern computer systems that can help physicians during their diagnosis. This article briefly describes a telemedicine system designed to acquire, monitor and control the clinical evolution of ICU patients. Our system follows a client/server architecture, which means that it consists of two related but independent subsystems: the local subsystem and the central remote subsystem. The applications that are installed in the local system, next to the patient's bed, obtain and visualize in real time the signals of his physiological parameters. These client applications can function autonomously or in a centralized way, and in the latter case they must transmit all the generated local information to the central remote applications. On the other hand, the central subsystem has total control over all the connected local subsystems, i.e. all the patients. The central applications receive the signals from the local applications and visualize them in a similar way.

Both subsystems are equipped with a series of multimedia options that improve the global system. Among these options are: videoconferencing communication (audio and video), collaborative whiteboard, transmission of all kinds of files and compression of these files before their transmission so as to exploit the bandwidth, and visualization of graphic files concerning the patient.

The system also includes an intelligent module that is in charge of tasks like the management of the communication between the different system processes, the data transmission

priorities for each type of information, the management or intelligent regulation of the used bandwidth, etc.

At present the system is being extended with certain improvements. We will for instance use the already existing databases of signals and medical records to safely consult data through the Web and show in a specific applet the physiological signals stored in the database. We are also developing adequate solutions to add multiprocessor functionalities to the system. This way, in critical cases a processor could dedicate itself exclusively to concrete tasks of maximal priority and relieve the rest of the system.

IV. BIBLIOGRAPHY

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