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Versatile and open tools for LAN, MAN and WAN communications with PACS

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ABSTRACT

Versatile and open tools for the communication with the data-base server of a Picture Archiving and Communication System (PACS) and the presentation of patients' medical images and records on a user-friendly graphic interface have been developed. They permit to use almost any MS-DOS, OS/2 or Macintosh personal computer, workstation or X-terminal as a low-cost, efficient and easy-to-use PACS remote station. The stations can be connected to the hospital Local Area Network (LAN) or to any remote site connected to the PACS LAN by a Metropolitan (MAN) or Wide (WAN) Area Network. Different solutions have been studied to optimize network traffic and resources in the various environments. A routing-authentication method has been used to filter rigorously the remote access to the PACS data-base.

INTRODUCTION

Picture Archiving and Communication Systems (PACS) have been proposed as a way to solve the problem of the largely increasing volume of medical imaging data. These systems handle and store images in digital form and communicate them through digital networks. Patients' data can be instantly available to the interpreting radiologist and to the referring physician at locations ranging from the radiology department to the other departments of the hospital or even to another hospital or remote health unit (tele-radiology). Simultaneous data access by multiple users is easily supported to both current and past exams. Moreover, computer-based display systems can offer image processing and analysis software to manipulate, enhance and compare image data. A PACS is mainly composed by four subsystems: a) acquisition, b) archiving and data-base, c) communication and d) processing, visualization and printing. Prerequisites for all these subsystems have been largely discussed and recently reviewed [1-2].

Diffusion and acceptance of PACS depend on many factors. Probably, the most important one, at least outside the Radiology Department, is the availability of efficient, economic and user-friendly tools for the PACS data-base query and image presentation.They should be compatible for any graphic computer resource accessible at the hospital or at any remote site of an Health Service, possibly with full integration with RIS (Radiology Information System) and HIS (Hospital Information System) facilities. Tools designed according to open standards, in particular to ISO/OSI (International Standard Organization / Open System Interconnect) [3] and OSF (Open Software Foundation) [4] can help very much for the solution of this problem. In this paper our contribution to an open and unitary solution for remote PACS stations is presented. It can be applied to MS-DOS, OS/2 and Macintosh personal computers, to UNIX and VMS Workstations and to X terminals. Access-controlled local, metropolitan and geographical connections to a PACS data-base are made available.

DEVELOPED TOOLS

The libraries PACS1-LIB and PACS2-LIB

Two basic libraries have been developed. The first one (PACS1-LIB) provides tools of communication with the PACS data-base (or its Gateway toward the outside network), following the specifications of the ISO/OSI seven-layer model [3]. The second one (PACS2-LIB) is a double collection of graphic objects compatible with the standard graphic interface OSF/Motif [4] and the Microsoft Windows graphic tools. These objects realize the user window interfaces for quering patients' data-base, selecting a patient, asking for selected exams, viewing data and images on the screen, processing and manipulating the images, storing them to or retrieving them from a local storage mass, etc. They have been written by means of the powerful object-oriented programming. Two application programs which use the two libraries PACS1-LIB and PACS2-LIB and many other standard libraries have been realized.

The application PACS-X

The first application program (PACS-X) interfaces OSF/Motif with the X-Window system, which is a distributed, network-transparent, device-independent, multitasking windowing and graphic system [5]. The X-Window separates the windowing functions into two distinct parts: the client and the server. The user works on a display system running the X-server, i.e. the program controlling the display. Both the user applications and the X-client run on a remote computer. The application PACS-X resides on the computer acting as an X-client. This computer, usually running UNIX, communicates with the PACS Gateway and manages all the user processes. PACS-X permits two operating modes.

The X station (XRIS) and the ImageServer In the first operating mode PACS-X is installed on a user-sharable computer with X-client capability (ImageServer). In this case the remote image station (XRIS) where the user is sitting on has the only function of a multiple X-server (Fig. 1).

Although the ImageServer communicates with the PACS gateway adopting its transport protocol (usually TCP/IP [6], as in our experimental implementation), the XRIS can communicate with the ImageServer by using any X-compatible transport protocol available on that computer. Other than a workstation or an X-terminal, an XRIS can be a cheap MS-DOS-compatible personal computer (PC) or a Macintosh with X-server capability (Fig. 1). We chose to use the Pathworks Network Operating System from Digital Equipment for PCs (running indifferently MS-DOS, Microsoft Windows or OS/2) and for Machintoshes as well. This environment offers many network services and, in particular, a multiple-session X-server capability.

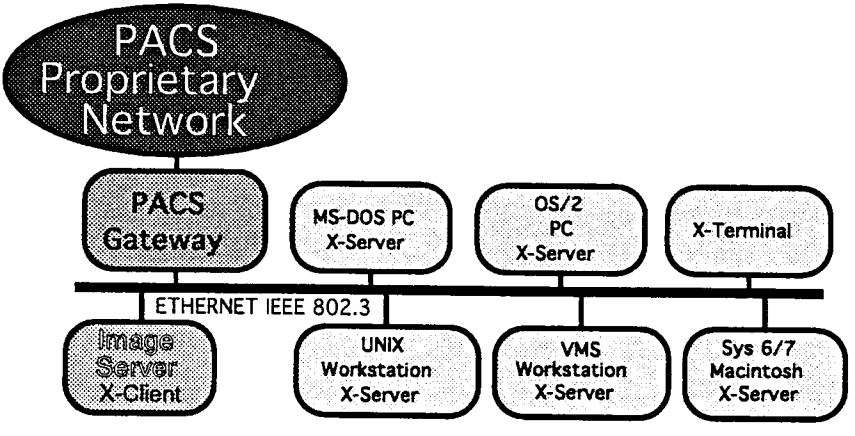

Figure 1. Ethernet LAN with XRIS stations communicating with the PACS Gateway through an ImageServer running the application PACS-X.

The autonomous station (ARIS) PACS-X can be installed also on a workstation with full X capability (Fig. 2), which behaves as an autonomous remote image station (ARIS) and connects directly with the PACS Gateway. Typically, an ARIS is implemented on a UNIX workstation; however, any other one offering the transport protocol of the PACS Gateway (i.e. TCP/IP, in most cases) can be employed, as a VMS workstation in which also TCP/IP is installed (Fig. 2).

The application PACS-W for a PC-based ARIS
The second application program (PACS-W) has been written specifically for PCs. It uses the windowing tools of Microsoft Windows or those of WIN-OS/2. PACS-W is an alternative to PACS-X with the aim to obtain an ARIS by using a cheap PC rather than a more expensive UNIX workstation (Fig. 2).
A third application (PACS-M) is still in progress. It will interface the Macintosh Multifinder windowing system, thus extending the capability of an ARIS also to this popular personal computer.

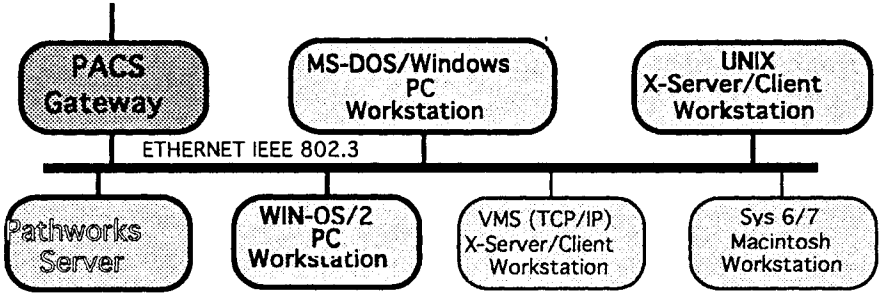

Figure 2. Ethernet LAN with ARIS stations running the application PACS-X or PACS-W and communicating directly with the PACS Gateway

ACCESS TO THE PACS DATA-BASE AND THE LIBRARY PACS1-LIB

The communication with the PACS data-base/archiving subsystem or its Gateway depends largely on the protocols used by its manufacturer. These protocols can adhere to the ISO/OSI model or not. In both cases, they can be standardized, as the ACR-NEMA protocol, proposed by the American College of Radiology and the National Electrical Manufacturers Association [7], or not, as that one used by AT&T for the communication over Ethernet of the Results Viewing Stations (RVS) with the PACS systems (model CommView) of its production. Since all the PACSes installed in Italy are of this type, including that one installed by our Local Health Unit at the Department of Radiology of the Hospital of Cattinara in Trieste, we chose to start by developing the PACS1-LIB for the communication with this system. We have in progress also a second set of routines compatible with the last version of the ACR-NEMA standard, named DICOM, which has been proposed few months ago [8]. This protocol, differently from its previous version, is largely adherent to the ISO/OSI model for all seven layers.

The AT&T COMMVIEW system communicates with the outside network by means of a computer running UNIX (PACS Gateway), equipped with an Ethernet interface (Fig. 1). The protocol used for this communication is not specified by the factory. However, from the analysis of the packets exchanged with an RVS we were able to find that the standard protocol TCP/IP is used and that the TCP connects to/from a daemon running on the Gateway by means of a couple of sockets on a fixed TCP port. We were able to reconstruct the logical talk exchanged with an RVS and the relative data codes. Therefore, we could build up completely the fifth (session), sixth (presentation) and seventh (application) layers of our communication protocol.

Main functions of the library PACS1-LIB

Calls to the application-layer modules of PACS1-LIB permit a user application to execute various tasks. The main ones are the following:

- establishment and closure of a session with the PACS Gateway
- query for the data-base of patients' records, with wildcard capability
- query for a set of medical images associated to a patient or to a particular exam
- transfer and decoding of the selected images and their temporary memorization on the disk of the computer which the communication program is running on (i.e. an ImageServer or and ARIS).

Implementation of the library PACS1-LIB

The library has been written in C language. Its lowest-level protocol, corresponding to the session (fifth) layer of the ISO/OSI model, connects with the TCP transport layer by means of an Internet socket (opened on the same port of the socket listening on the PACS Gateway). Managements of the socket, i.e. opening, data communication and closure, are made thanks to calls to a socket library, addressed for Internet TCP connections. This library is standard for any computer running UNIX. The extension of this standardization to PCs running MS-DOS or OS/2 in autonomous mode (ARIS), has been realized with the adoption of the Pathworks for DOS (TCP/IP) Network Operating System. This environment offers a socket library almost totally call-compatible with the UNIX one. So, we were able to build up a unique library PACS1-LIB callable from an application running on almost any platform.

THE GRAPHIC LIBRARY PACS2-LIB

The library PACS2-LIB is a collection of objects, which can be used by an application in order to realize a powerful and friendly interface with the user. It has been written in C and C++ languages. Almost every object of the library can be directed to either the OSF/MOTIF Graphical User Interface and the X-client protocol or to the graphic tools of the Microsoft Windows system. So, the programmer can write easily an application largely portable to any platform. Figure 3 shows an example of user interface on a PC-based ARIS, where the application PACS-W is running and uses the objects of PACS2-LIB and the communication tools of PACS1-LIB.

Objects of the library PACS2-LIB

The main objects implemented on the library PACS2-LIB control the following functions: Exam List, Patient List, Load Exam, Load Patient, Permanent disk storage, Icone visualization of a set of medical images, Image full/half screen visualization, Image processing and Local data-base managements. Most of the functions can be seen in the example of Fig. 3. Records and images memorized on either the PACS data-base or a local data-base can be the target of these functions. If an ARIS is employed, the local data-base resides on that station. Differently, an XRIS user utilizes a personal or group-shared local data-base memorized on the ImageServer. This permits to create, maintain and use quick-access personal or speciality data-bases and to optimize the network traffic.

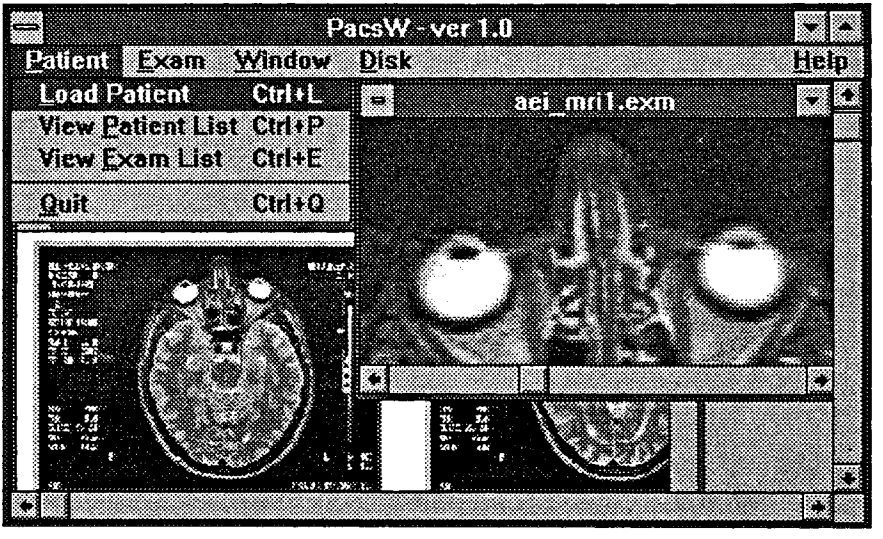

Figure 3. Example of a PACS-W session (partial view of the window manager).

LOCAL EXTENSIONS OF THE PACS DATA-BASE ACCESS

In Figures 1 and 2 an XRIS or ARIS was connected directly to a 10Mb/s Ethernet Local Area Network (LAN) of the PACS Gateway. However, an XRIS can be easily connected to any other LAN of the Hospital, working with the same or different protocol (Fig. 4). For example, an IP router can route the IP packets from the ImageServer to an XRIS on a Tokenring LAN. Furthermore, a Macintosh-based XRIS can be part of a low-speed Apple LocalTalk LAN,

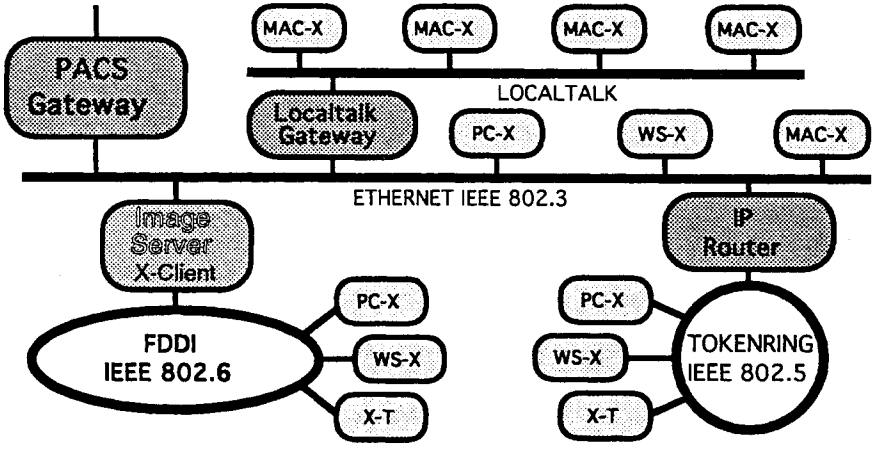

Figure 4. Extension to an etherogeneous local networking of the access to the PACS Gateway from XRIS stations.

connected to the Ethernet through a Localtalk Gateway.
Moreover, a powerful 100Mb/s FDDI LAN can be employed for high-speed applications. In this case, the best solution is to connect the ImageServer to both the Ethernet and the FDDI, so that an XRIS on the FDDI can take advantage of the very fast access to the local data-bases stored on the ImageServer, overcoming the relative slowness of the direct access to the PACS data-base.
Other than an XRIS, also an ARIS with TCP/IP protocol can be efficiently used on Tokenring and LocalTalk LANs. A similar connection to the FDDI is possible (for example by routing the IP on the ImageServer), although the XRIS or other mixed solutions are preferable for speed considerations.

METROPOLITAN (MAN) AND GEOGRAPHIC (WAN) ACCESSES

MAN access

We experimented the good efficiency of tele-radiology applications using either the XRIS and the ARIS. The Hospital of Cattinara and all the scientific institutions of Trieste are connected together by means of an experimental 34Mb/s Metropolitan Area Network (MAN). Ethernet gateways are available on each site, so that the MAN is equivalent to a fast metropolitan Ethernet (Fig. 5). For management and security opportunities we chose to separate each site with a multiprotocol router. All the XRIS and ARIS configurations experimented locally at the Hospital of Cattinara have been successfully ported to the MAN environment. The high speed of the MAN permits a powerful use of an XRIS installed on any site and connected to the ImageServer at the Hospital of Cattinara. However, to reduce the heavy traffic due to the X-protocol, it is more convenient to have one ImageServer at each different site where many XRISes are used.

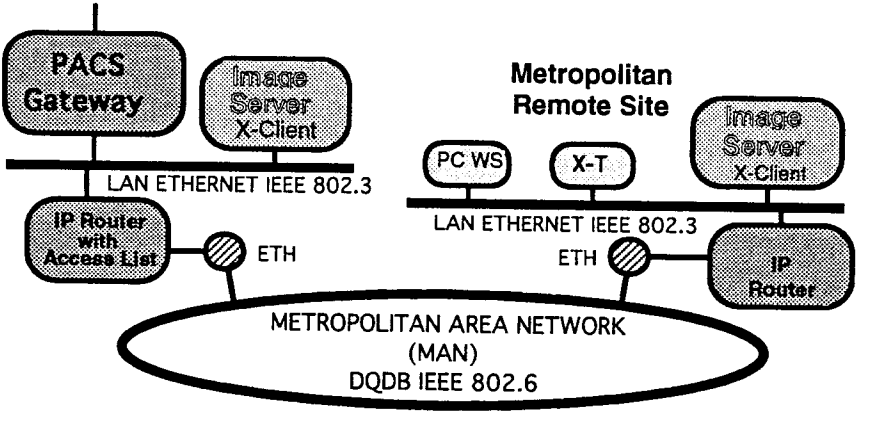

Figure 5. Access from XRIS and ARIS stations located on a metropolitan remote site connected to the LAN of the PACS Gateway through a Metropolitan Area Network (MAN). A serial-line connection from a router on the MAN (not shown in Figure) extends the network to the worldwide WAN.

WAN access

We experimented successfully our image stations also in the Wide Area Network (WAN) geographic environment. No limitations have been reported with respect to the local or metropolitan environment except those due to the lower speed of the connections and to the need to limit the geographic traffic. For these reasons,the use of a remote XRIS should be avoided, unless an Image Server is installed in that site.

Access authentication

A big problem of security on the access to data and medical images arises when communications are extended outside a Hospital. Although access controls are made usually at the session level (user-id and password) and often at the presentation (cryptography) or application levels, we chose a more radical solution: the entire IP subnet where the PACS Gateway and the ImageServer are configured was not routed to the MAN nor to the worldwide Internet. The IP router which connects the PACS site (the Hospital of Cattinara) to the MAN (Fig. 5) denies this routing with the exception of the authorized IP nodes (XRIS, ARIS or remote ImageServer) which are contained in an access list.

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