TeleTeaching and TeleGuiding using an IntraNetwork: a Feasibility Study

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Abstract

Telemedicine (more specific TeleCardiology), including teleteaching and teleguidance, is a rapidly growing area in cardiology. The availability of hand-held network ready ultrasound equipment is one of the accelerators for furthers developments.

A pilot project for both teleteaching and –guiding was started in our institution. For teleteaching the requirements were not too strict, e.g. no real-time interaction with the remote site necessary and some loss in image quality was allowed. For teleguidance however, near real-time transmission of images with no loss in diagnostic quality was demanded.

For both teleprojects solutions were found and/or developed with complete satisfactory to the clinical demands.

1. Introduction

Telemedicine[1-3] (more specific TeleCardiology), including teleteaching[4] and teleguidance[5], is a rapidly growing area in cardiology[6, 7], in both technology as in attention. The availability of hand-held network ready ultrasound equipment[8] is one strong accelerator for further developments.

Although a topic which is being explored for a long time, the technology necessary to transmit in real-time images, sound and other signals via computer networks was still too limited to be able to perform cardiologic teleguiding procedures[9] such as tele-echocardiography. The interaction necessary in these cases, ultrasound examinations of the beating heart, between operator and receiver, must be fast and so only small delays between transmission of the signals and receipt are allowed. Most developed, described and available applications in medicine are limited to static images and simple waveforms with low sample rates only (e.g. by example blood pressure measurements over time).

For teleteaching purposes the requirements may be looser and is therefore probably easier to implement with available commercial products.

A pilot project for teletcardiology was setup using an intranetwork in our University hospital.

2. Requirements

One the shared requirements for both projects was the used type of network stream. There are basically two types: 1) unicast, can be used for private communications or to transmit to machines that cannot receive a multicast stream and 2) multicast, is an efficient way to transmit to several clients simultaneously. The choice was made to be able to transmit the streams both ways. Although multicast streams preserves network bandwidth, not all networks are capable of handling a multi-megabit multicast stream.

2.1. Teleteaching

The requirements formulated to perform teleteaching were to send images from a clinical site (operation theatre, catheterisation laboratory or outpatient clinic) to a college hall to educate students or to a conference site to transmission so-called "live cases" to educate medical professionals (Figure 1).

Figure 1. Teleteaching at the Thoraxcentre

The time between transmission and receipt should be short and good image quality. Two video channels must be transmissioned: 1) one channel of a video camera showing an overview of the clinical site and/or the treating physician and 2) one to show images of a medical image modality (by example angiography, ultrasound, etc.), plus a full-duplex speech channel.

2.2. Teleguiding

For teleguiding the requirements were stricter. The time between transmission and receipt of the signals must be absolutely minimal, preferable operating in real-time. This to avoid “the man on the moon effect”, e.g. the time between an advise send from the remote site will be heard and executed at the transmission site with a certain time delay. If this delay is more than seconds, people will think that it is not heard and start repeating what they said. It will also make further verbal communications between the sites difficult and one will start talking at the same time at the two sites, and receiving it later.

The diagnostic qualities of the transmitted medical image modality must be preserved so that there is no loss in diagnostic capabilities at the remote site.

Besides these clinical requirements, one technical important requirement was that the implemented solution should be flexible (e.g. modular), this to be able to integrate telemedicine in the already existing computer environment and to implement future additional clinical requirements.

3. Materials and methods

Besides the used hard- and software described in the next two sections (3.1. and 3.2.), both teleprojects requires fast network connections. The network in our institution has a gigabit backbone with side branches operating on 10 or 100 Mb/s. For both projects all connections to the transmission and remote locations were upgraded to 100 Mb/s.

For both projects a technique called streaming video was used. Streaming video does not send a complete video file to the client, but stays completely at the video-server at the transmission site. Only a part of the file will be sent and played directly at the client connection. If streaming video technology is not used, the complete file must be transported first, which can take hours, before it can be played, which is not useful for teleguiding. Streaming video can work for uni- as well for multicast connections.

3.1. Teleteaching

At first a commercial solution was being sought. For teaching one was found in the hard- and software of the Osprey framegrabber card (Osprey Video, Morrisville, NC, USA). This frame grabber is the de facto Internet web standard card used to transmission live events on the Internet. The accompanying software that comes with the card allows setting image compression so that almost every requirement for network connections in case no high speed connections can be met. To connect with the video stream, the windows media player can connect to the cards URL (Uniform Resource Locator) address.

3.2. Teleguiding

For teleguiding the above-mentioned solution did not fulfil the requirements, which will become clearer in the result section. The biggest problem there was the encountered time delay, which for teleguiding must be brought back to an absolute minimum. On the commercial market no system could be found which met all requirements, at this moment. Fortunately, hard- and software was found via the University of Berkeley. The hardware is a LML-33 frame grabber card (Linux Media Labs, Colorado Springs, CO, USA), which only can operate under the Linux operating system, and the software used was RTPtv (University of Berkeley, San Francisco, CA, USA) (Real-time Transport Protocol). This software is capable to send and receive “transmission quality” television (audio and video) over IP using the IETF RTP protocol (Internet Engineering Task Force) and M-JPEG (M-JPEG stand for “Motion JPEG”, where each video frame/field is sent as a single JPEG image). The production TV quality streams send video as 60 field/sec, full-sized 4:2:2 video images compressed MJPEG with 16-bit PCM (Pulse Code Modulated) audio sampled at 44 KHz. The video and audio transmission bandwidths are 10-20 Mbps and 1.4 Mbps, respectively.

At the remote site the above-described system must be set-up as well. Neither the RealPlayer nor the Windows Media Player are RTP-compliant, and none of these implementations appear to be capable of operating under low-latency conditions.

So in short, the overall process of the RTPtv software is to obtain audio and video data from the hardware, fragment the data into RTP packets, transport the packets across a network, receive the packets on a client machine, reassemble the data, and playback the audio/video via hardware. This implementation was used to send images preserving diagnostic capabilities. Two different types of cameras were used to present images of the examination room from the remote site. 1) A commercial IP ready camera, AXIS 2120 (AXIS Communications AB, Lund, Sweden) combined with an IP ready audio server, AXIS 2191; 2) A moveable camera via a standard Internet browser, AXIS EVI D31 (PAL), this camera was connected to a Linux station and the images transferred via the above described protocol used for the “medical images”. Using solution 1, the images from the examination room can be viewed via a standard Internet browser, or can be viewed via a self-developed windows application. Both systems are actually developed and mostly used for remote surveillance (e.g. guarding) situations. Figure 2, shows the layout of the implementation. The two required video-streams are consuming 12 Mbps network bandwidth each. The audio stream requires 1 Mbps bandwidth and should theoretically be in CD quality (44 KHz, 16 bit).

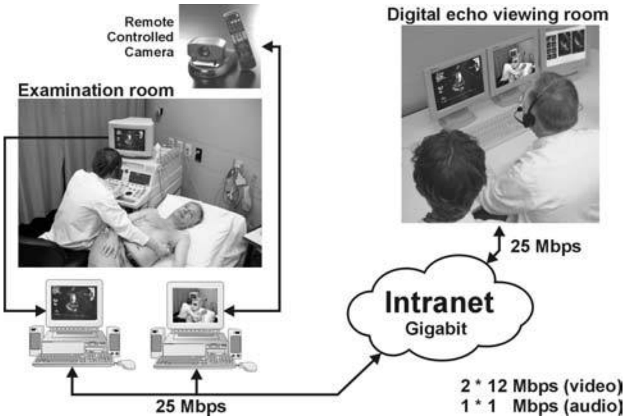

Figure 2. Teleguiding.

4. Results

4.1. Teleteaching

The teleteaching solution provided a well-appreciated video- and audio playback quality, using commercial available hard- and software, at the cost of a 15 seconds delay at the receiving site.

4.2. Teleguiding

The 15 seconds delay was of course not suitable in situations for teleguiding. This requires direct interaction. The found and described solution delivered diagnostic quality images at the receiving site with almost no delay (< 1 second). From the used cameras, the movable one seems to be well fitted in situations were the remote physician couldn't move the camera since he is busy examining the patient. To have this capability plus zooming functionality is mandatory.

5. Discussion

This pilot-project is just the start in our institution using computer networks to show and guide medical examinations at different locations. It can be expected that when the medical staff sees and start to use this new technology a whole new cargo-load of wanted functionality will arrive. This area of computer development is moving rapidly and we can only surf on the wave caused by the demands from the entertainment Industry. However, in University hospitals the requirements and implementation is usually slightly different than what can be bought commercially. Therefore, open systems and sources are requested to be able to implement this technology into the already existing information technology environment. The RTPtv solution is a relatively cheap one, with free software sources that can be used into own developments. However, it is developed by researchers and therefore it is not as we are used too a stable commercial end-product for which a service organization is available (e.g. helpdesk, hard- and software upgrades, etc.).

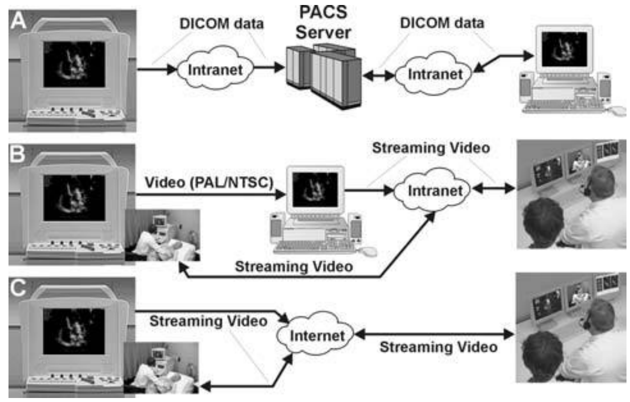

Figure 3. Echo image data streams.

Figure 3 shows the different pathways and solutions the echo image data can take. Track A, shows what can be bought commercially, today, and used in many hospitals which transferred from analog (e.g. video-tape) image data storage to a digital solution. After the ultrasound examination, the image data must be uploaded to a picture archiving system (PACS) in the medical DICOM image format. After this, at the remote site this DICOM data can be retrieved from the PACS system for further evaluation. So there is no real-time interaction possible between the two sites. Track B, shows our real-time guiding solution. The analog video-output of an ultrasound system is captured, digitized and transformed into a real-time video-stream, which can be observed at a remote site. Since there is a full-duplex speech channel, the physician at the remote site can give comments and directions. Track C, shows the ideal "future" solution where the ultrasound console is capable to send real-time digital video over a network (DV over IP).

Further implementation requirements will be a connection to other patient data like lab results and earlier made and other medical image diagnostics (e.g. MRI, ultrasound, x-ray, etc.).

The next step after the Thoraxcentre is fully remote video operable is to connect referring hospitals in the Rotterdam area to the Thoraxcentre. However, that raises the question how to secure the video and audio streams via the Internet. Developments for secure transmission over the Internet are on their way, like virtual private network or secure network tunnels. For teaching purposes such security measures can already being found in the latest operating systems such as Windows™ 2000 server, which provides a secure Windows™ media server for sending secured video streams from behind a firewall.

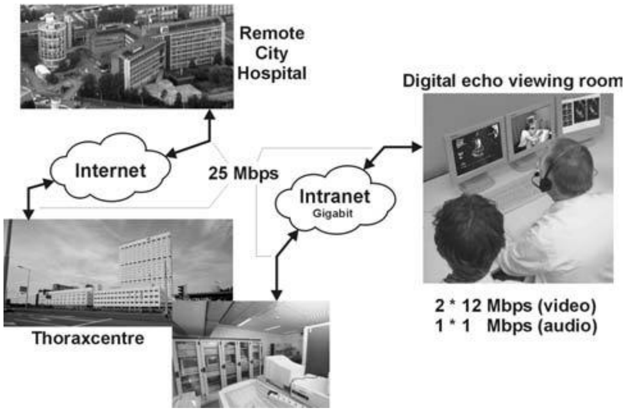

Figure 4. Remote hospital connection.

6. Conclusion

Teleteaching can be performed using relative cheap commercial products, which can be easily installed and maintained by already existing IT-helpdesks.

Teleguiding can be performed using high quality video streaming without loosing diagnostic quality. However, further developments and tests are necessary to make this a stable technology ready for widespread use.

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