Digital Image Data Transmission over Long Distances Using Image Compression and Broadband ISDN

T Becker, R Simon

University Hospital Kiel – Department of Cardiology, Kiel, Germany

Abstract

For telecardiological applications transfer techniques with very large bandwidths are required. Because of the high costs, these techniques are not applicable for the broad community. For the data transmission between two hospitals, that are over 80 kilometers apart, we have managed to bundle 30 common ISDN base channels into one logical line. The image data are compressed by factor 6 using JPEG image compression and encoded according to the DICOM standard.

The system needs 15-20 seconds to build up a connection with the 30 channels and reaches transmission speeds up to 1.6 Mbit/s. The transmission of a cardiac study with 1500 frames takes 5-6 minutes. After the transmission, the image data are made available in the department PACS. This system allows physicians to access the transferred image data from any cathlab or from their offices without delay.

1. Introduction

During the last years digital image networks and archiving systems have become more and more common in cardiology. Due to the high amount of image data in an angiographic study, these systems require fast networks, that are only available in local areas. This technique cannot be used for data transfer over long distances.

In the presented project a 30 channel ISDN connection between the cardiological departments of the University Hospital Kiel and the General Hospital in Heide (both located in northern Germany) is described. Although the distance between these hospitals is over 80 km, there is close cooperation. The goal was to enable the remote hospital to send angiographic image data to the University Hospital with the purpose of consulting, to get a second opinion and to prepare patient transfers.

The usage of standard technology leads to unpractical long transfer times. The transfer of a complete angiographic study including 1500 frames over an ISDN base channel (64 kBit/s) takes more than 6½ hours.

A possible solution for image data exchange over long distances would be to hire special lines, that are relative expensive.

In order to reduce transfer time, two approaches are possible: Data compression and bandwidth extension. Both techniques are used in this project and will be described in the following paragraphs.

1.1. Data compression

A straight method to reduce the amount of data is to remove unimportant information ('intelligent compression') and reduce transmission to the relevant image data. This kind of image reduction should be avoided, because this is a relevant information lack for the receiver and can decrease the quality of his findings significantly. Furthermore this requires a time consuming manual selection process, which might be a limitation in routine work.

Another method is to use digital image compression techniques like the JPEG (Joint Photographic Expert Group) or MPEG (Moving Pictures Expert Group) algorithms. Both compression schemes eliminate redundant image information and reduce the amount of data in dependence from the required quality. In an international multi-center study it was found, that JPEG compression with factor 6 does not lead to relevant changes in clinical data contents, and more important, to changes in decision making. The results of this study can be applied for angiographic image sequences acquired in the 512x512 matrix with 8 bit depth using conventional image intensifier technology [1-3]. The mentioned compression factor 6 coincides with a quality factor of 94-96. An empiric relation between compression and quality factor is described in [4]. A similar survey for the MPEG algorithm has not been performed yet.

1.2. Bandwidth extension

The second approach to reduce transfer time is the extension of the available bandwidth using standard technology. The aim is to find standard technology, that is available everywhere in the target area and is less expensive than exclusive lines.

In Germany the ISDN technology is available all over the country. More recent technologies like DSL are still limited to large cities and did not proof their stability. ISDN offers the possibility to bundle a number of base channels (S_0) to one logical line. A practical size is to

Compression Factor (CF)	Data Capacity	Number of base channels used for transmission		
		1 channel	*6 channels*	*30 channels*
CF 1:1	375 MByte	802 minutes	134 minutes	27 minutes
CF 2:1	187,5 MByte	401 minutes	67 minutes	14 minutes
CF 6:1	62,5 MByte	134 minutes	23 minutes	4.5 minutes

Table 1. The transmission time can be reduced by higher data compression and increasing the number of ISDN base channels. A cardiac study with 1500 frames, using a 512x512 matrix with 256 gray levels, is assumed.

bundle all 30 channels of a primary multiplex (S_2m) line. The price to hire a primary multiplex line is about 10% of a permanent 2 MBit line.

For channel bonding special equipment is necessary, that organizes data transfer over the single lines, synchronizes signal delays and handles the protocol.

1.3. Estimated transfer time

In Table 1 the data capacity and required time for the transmission of a cardiac study, that contains 1500 frames assuming a 512x512 matrix with 256 gray levels, are compared. A JPEG lossless compressed study with an assumed compression factor of 2 requires a data capacity of 187,5 Mbyte and can be transferred over a single ISDN base channel in 401 minutes. Using a compression factor 6 and bonding of 30 channels the transfer time can be reduced by factor 90 down to 4.5 minutes.

2. Implementation

For the connection between the two cardiological departments a 30 channel ISDN line is used. Each node is using a OASIS 500© bandwidth controller, that bundles and synchronizes up to 30 channels. This controller is connected to a router, that translates the internal to the TCP/IP protocol. The whole setup can be accessed via a usual IP point-to-point connection.

Figure 1 shows the components involved in the data transfer. The remote hospital creates a DICOM offline medium (CD-R), that contains the angiographic image data. The medium is inserted into a viewing station, that handles the complete transfer process. The image data are compressed, using the JPEG compression algorithm applying the quality factor 95, and stored in DICOM format to the hard disk. Either the sending or receiving station can establish the ISDN connection and initialize the data transfer. When the transfer is completed, the connection is shut down.

During the data transmission, the receiving viewing station is only connected to the remote hospital and not to the local network. All data are stored on the receiving workstation first. When the transmission has been completed, the image data can be reviewed directly at this viewing station. In daily practice, these data are forwarded to the image archive system MARVIN [5]. For that the viewing station must be disconnected from the ISDN line and connected to the local network. This design allows maximal security for the in-hospital data network.

The received image data in the archive system are marked to be acquired in a remote hospital. This allows quick and easy queries and gives in-house physicians direct access to the new image data independent from their current localization in the hospital. The data can be accessed using one of over 40 workstations in the departments for cardiology, pediatric cardiology and surgery.

3. Results

The required time to establish a connection is less than 20 seconds. The transfer of a full angiographic study takes about 4 minutes. The amount of acquired data is in average 45 Mbyte (1080 frames), which is less than the expected 62 Mbyte (1500 frames) in the design phase. Nevertheless, the transfer speed is as high as expected and allows very short transfer duration.

Additionally to the pure transfer time there is a delay caused by general administrative workflow. For example the physician in the remote hospital needs to inform the University Hospital, that new image data are or shall be transferred. After completing the transmission, the referring in-house physician must be informed. The total time from the decision to transfer data to the first possible reviewing in the receiving house is about 15 minutes.

The described data transfer is now working for over 15 months. The technical equipment is working almost automatically. Sometimes (less than 5 %) of the cases, the dialing is interrupted and requires a controller reset.

4. Discussion

The connection was established the first time early 2000. At that time, less than one examination per week has been transferred. The present status is, that 4-5 exams are transferred per week. This indicates, that the users made good experiences with this technique and makes much more use of it than in the beginning. But the success of this kind of teleconsulting is not only guaranteed by a proper working technical solution. It also requires a quick and qualified response in terms of service for the remote hospital. This requires motivated physicians on both sides.

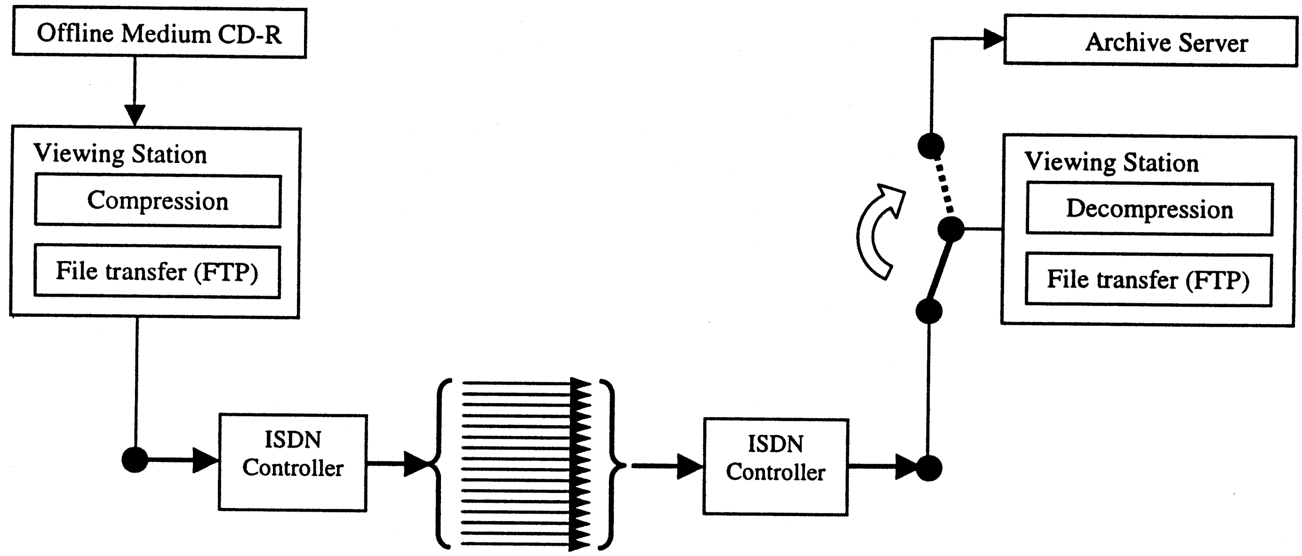

Figure 1. The image data are read from CD-R and compressed using the JPEG algorithm and quality factor 95. Both on CD-R and for the data transfer, the data are stored in the DICOM format. For the transfer a 30 channel ISDN connection is used. The receiving workstation is either connected to the remote node or to the local network.

Although the communication is established by standard ISDN lines, the additional equipment is very specialized. For this kind of equipment, there must be spare systems in or close to the hospital available.

5. Conclusion

It can be concluded, that image compression techniques and broadband ISDN together reduce the transmission time of a full cardiac study to an acceptable magnitude. Transferring all image data using a compression factor of six saves the full amount of information and makes remote diagnostic possible. The presented project fulfils the requirements of a quick data transfer of a complete cardiac study with high image quality.

The required technology is already available and costs about 10% of exclusively hired lines. Furthermore a single node can be used for connections to different destinations, which makes it economically even more attractive.

References

[1] Kerensky RA, Cusma JT, Kubilis P et al. American College of Cardiology/European Society of Cardiology international study of angiographic data compression phase I; the effects of lossy data compression on recognition of diagnostic features in digital coronary angiography. European Heart Journal, April 2000; 21 (8); 668-678

[2] Brennecke R, Burgel U, Simon R, Rippin G, Fritsch HP, Becker T, Nissen SE. American College of Cardiology/European Society of Cardiology international study of angiographic data compression phase III; measurement of image quality differences at varying levels of data compression. European Heart Journal; April 2000;21 (8);687-696

[3] Tuinenburg JC, Koning G, Hekking E, Zwinderman EH, Becker T, Simon R, Reiber JHC. American College of Cardiology/European Society of Cardiology international study of angiographic data compression phase II; the effects of lossy data compression on the quantitative assessment of the degree of stenosis in digital coronary angiography. European Heart Journal;April 2000;21(8); 679-686

[4] Onnasch DGW,. Prause GPM, Plöger A. Objective methods for optimizing JPEG compression of coronary angiographic images. International Journal of Cardiac Imaging;1995;11;151-162

[5] Becker T, Simon R. A digital archive solution for multiple modalities in a cardiological department. Computers in Cardiology 1999;26;367-9

Address for correspondence.

Tim Becker
University Hospital Kiel
Department of Cardiology
Schittenhelmstr. 12
D-24105 Kiel, Germany
becker@cardio.uni-kiel.de