Proceedings of the 28th IEEE
EMBS Annual International Conference
New York City, USA, Aug 30-Sept 3, 2006

The Effects of Wireless Channel Errors on the Quality of Real Time Ultrasound Video Transmission

Carolina Hernández, Álvaro Alesanco, Violeta Abadía, José García

Abstract—**In this paper the effect of the conditions of wireless channels on real time ultrasound video transmission is studied. In order to simulate the transmission through a wireless channel, the model of Gilbert-Elliot is used, and the influence of its parameters in transmitted video quality is evaluated. In addition, the efficiency of using both UDP and UDP-Lite as transport protocols has been studied. The effect of using different video compression rates for XviD codec is also analyzed. Based on the obtained results it is observed as the election of the video compression rate depends on the bit error rate (BER) of the channel, since the election of a high compression bit rate for video transmission through a channel with a high BER can degrade the video quality more than using a lower compression rate. On the other hand, it is observed that using UDP as transport protocol better results in all the studied cases are obtained.**

I. Introduction

Of the numerous fields that Telemedicine covers, it emphasizes the importance of those destined to provide healthcare services to patients with cardiopathies, mainly those that have chronic character. In most of these cases, patients must travel long distances before arriving at hospital where cardiologists perform periodical follow-up of the disease [1]-[3].

Echocardiography is frequently used to diagnose the seriousness of a patient and for chronic diseases monitoring. This technique is based on the registry of ultrasound video and presents several advantages over other techniques of medical images: it is noninvasive, it does not produce ionized radiation and it is relatively cheap. For these reasons, the use of the communication networks to transmit ultrasound video from the closest primary health center to the patient, or even its home, supposes a saving in time and money for the patient and for health services. In many of the application scenarios, a wireless channel is required to transmit the information. This means some problems associated to the channel, such as the high error rate and the fadings of the signal.

This work was supported by project TSI2004-04940-C02-01 from Comisión Interministerial de Ciencia y Tecnología (CICYT) and European Regional Development Fund (ERDF), FISPI051416 from Fondos de Investigación Sanitaria (FIS) and VI Framework Programme: IST-27142 PULSERS II IP.

Carolina Hernández (chramos@unizar.es), Álvaro Alesanco (alesanco@unizar.es) and José García (jogarmo@unizar.es) are with the Communication Technologies Group (GTC), Aragón Institute for Engineering Research (I3A), University of Zaragoza, Spain.

Violeta Abadía (violeta_abadia@msn.com) is a Telecommunication Engineering student at the University of Zaragoza, Spain.

Traditionally, real time applications have used UDP (User Datagram Protocol) as transport protocol [4]. UDP is a non connection oriented protocol, which allows starting a communication without making the process of establishment before, and does not use retransmission either. This means that UDP is a suitable protocol for communications with strict time requirements, as it is the transmission of real time video. If there is an error in the datagram, the packet is discarded and the information is lost. UDP-Lite [5] is a protocol based on UDP that detects errors only in the header of the datagram and, optionally, part of the data, allowing that information arrives, although it is erroneous.

In order to transmit information in real time it is necessary to do the compression of ultrasound video with the purpose of optimizing the use of network resources. A common solution to compress ultrasound video has been the use of nonspecific methods of codification and compression for standard video, like those used for the codification of movies [6]-[7].

The compression and transmission of ultrasound video do not have to degrade the quality of the images, preventing to do a medical diagnosis from them.

In this article, the effect of the conditions of the wireless channel on the quality of the transmitted ultrasound video is studied, and the efficiency of using both UDP and UDP-Lite protocols is evaluated.

II. Materials and Methods

A. Echocardiograms

The ultrasound video used in this study was acquired in the consultation of a cardiologist using a portable ultrasound device, SonoSite SonoHeart Elite, connected to a computer by means of a video capture card, Plextor ConvertX M-402U. It is a video sequence of 12 minutes of duration, with a frame rate of 25 fps and a resolution of 640x480 píxels, each pixel is codified in RGB24 format (24 bits per pixel). It is a representative ultrasound video that shows the different echocardiography modes: 2D Mode, Color Doppler Mode, Pulsed and Continuous Doppler Mode and M Mode.

The source ultrasound video sequence has high requirements of bandwidth to be sent in real time through a wireless channel (approximately 180 Mbps). For this

1-4244-0033-3/06/$20.00 ©2006 IEEE.

reason, the compression of the video using XviD is used [8]. This codec based on standard MPEG4 is open source and allows to do the codification in real time, obtaining videos of good quality using low bit rates.

From the source video sequence, some trace files of compressed video are obtained using different bit rates. In these trace files, information referring to each frame is stored: number of sequence, sample time, frame size and frame data.

B. Transport Protocol

With the information of each frame, a packet encapsulated through the protocol stack is built, adding the headers corresponding to the protocols of each layer. The UDP and UDP-Lite transport protocols are used. The header of the UDP datagram consists of four fields: source port, destination port, length and checksum. The *length* field specifies the length of the entire datagram: header and data, and the *checksum* field is used for error-checking of the header and data. If there is an error in the UDP datagram, the checksum will not be correct and the package will be rejected. UDP-Lite datagram is similar to the UDP one, but the *length* field is replaced by the *coverage* field, that indicates the number of bytes covered by the checksum to do error verification. Therefore, if the *coverage* field only includes the header, packets with errors in the data will not be discarded. The protocol of the network layer is the Internet Protocol (IP). For this study, header errors are not considered, since most of wireless network protocols do a header compression, being reduced to a few bytes that are negligible in relation to the data length [9].

C. Wireless Channel

In order to simulate the behaviour of the transmission through a wireless channel, a model of Gilbert-Elliot channel is used [10], whose principle of operation corresponds with a two-state Markov chain (Fig 1).

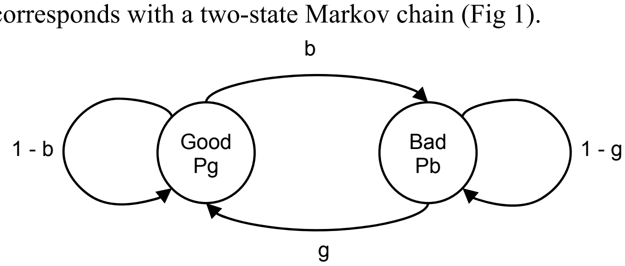

Fig. 1. Model of Gilbert-Elliot Channel.

As it is observed in Fig.1 there is a *Good* state where the bit error rate (BER) is *Pg*, and a *Bad* state where the BER is *Pb*. The probability of error in the *Good* state is considerably smaller than in the *Bad* state one. Parameters *b* and *g* represent the probability of transition from the *Good* state to the *Bad* one, and from the *Bad* state to the *Good* one, respectively. The following expressions show the relation between the probabilities of transition and the properties of the channel,

$$g = \frac{1}{ABL}, \quad (1)$$

$$b = \frac{BER - Pg}{ABL \cdot (Pb - BER)}, \quad (2)$$

being BER the average bit error rate of the channel and ABL, the average length of the erroneous bit bursts. The variation of these parameters will influence in the rate and duration of the erroneous bursts.

D. Received Video Evaluation

After transmission through the channel, the packets are desencapsulated to obtain the data referring to each video frame. If a frame is rejected and does not arrive at its destination, it is replaced by the previous frame, to maintain the video frame rate. Data frame is decompressed and it is compared with the corresponding frame of the source video to evaluate the loss of quality produced after the compression and transmission process. In order to quantify this loss of quality, the index of distortion PSNR (Peak Signal to Noise Ratio) is used, which is calculated by means of the following expression:

$$PSNR = 20 \cdot \log_{10}\left(\frac{255}{\sqrt{MSE}}\right), \quad (3)$$

$$MSE = \frac{1}{M \cdot N} \sum_{y=1}^{M} \sum_{x=1}^{N} \left[I(x,y) - J(x,y)\right]^2, \quad (4)$$

where *MSE* is the mean squared error, *I(x,y)* is the source frame, *J(x,y)* is the decompressed frame, and *M* x *N* is the frame dimension in pixels.

III. Results and Discussion

In order to evaluate the effect of real time ultrasound video transmission, two different channel models were studied. One with a bandwidth of 384 Kbps, characteristic of UMTS (Universal Mobile Telecommunications System), and another one with a bandwidth of 1 Mbps to evaluate the transmission in a Wi-Fi network.

TABLE I
CHANNEL AND VIDEO PROPERTIES

Protocols	Channel Bandwith (Kbps)	Compression Bit Rate (Kbps)	ABL (bytes)	BER
UDP	384	64 128 384	10 50 100 500 1000 5000 10000	10^{-6} 10^{-5} 10^{-4} 10^{-3}
	1024			
UDP-Lite	384	64 128 384 768 1024	10 50 100 500 1000 5000 10000	10^{-6} 10^{-5} 10^{-4} 10^{-3}
	1024			

In both channel models, the bit error rate in the *Bad* state (*Pb*) was 10^{-2}, and in the *Good* state (Pg) was 10^{-7}. The rest of considered properties used to study their influence in the quality of the received video are presented in Table 1. For every possible combination of these parameters, transmission of compressed video was considered for both protocols, UDP and UDP-Lite, and for each combination of parameters, the transmission was repeated 10 times, with the purpose of obtaining a significant statistical average of the results, yielding a total of 4480 video transmissions.

The effect of BER on transmitted video quality for both protocols is shown in Fig. 2. The represented results correspond to the transmission of compressed video using a codec bit rate of 384 Kbps, on a channel with a bandwidth of 384 Kbps and ABL values of 10, 500 and 10000 bytes. Observing the results it is noticed that when BER is increased, transmitted video quality diminishes, and for the same BER value when ABL is higher, better PSNR results are obtained. Comparing both protocols a clear superiority of UDP is observed in all the cases, which is more marked when BER is higher.

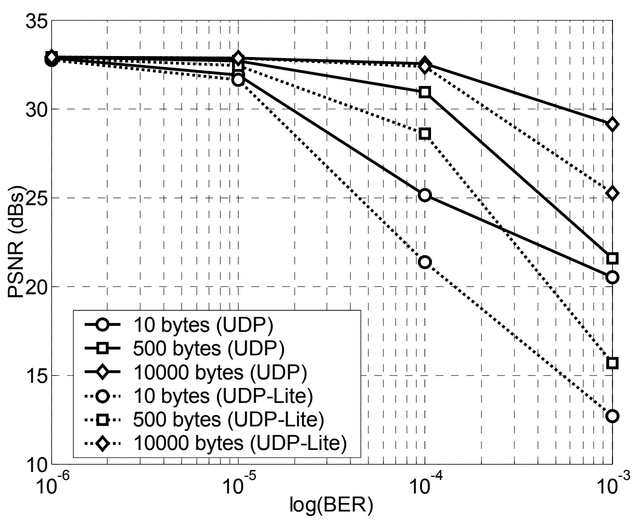

Fig. 2. Comparison of BER influence on video quality for UDP and UDP-Lite.

The influence of BER on video quality is shown in Fig. 3, but now, the behaviour for the different bit rates used in the video compression is evaluated. In this case, video transmission using UDP on a channel with bandwidth of 1 Mbps and ABL of 500 bytes is studied. Fig. 3 shows the joint effect of the compression error and the errors introduced during the transmission through a wireless channel. The PSNR values in the Y axis show only the compression error, considering the transmission through an ideal channel, without errors. When compression bit rate is increased, video quality is improved. However, when increasing the channel BER, video quality sets worse, being this effect more noticeable when compression bit rate is higher. This is due to when high compression bit rates are used, compressed frames are larger and therefore, more exposed to be affected by channel errors.

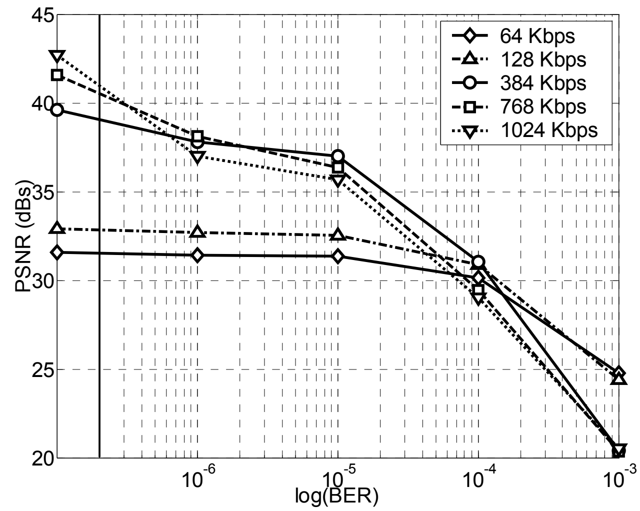

Fig. 3. BER influence on video quality for every compression bit rate using UDP.

Effects of real time compression and transmission on subjective video quality are shown in Fig. 4, Fig. 5 and Fig. 6. The first picture corresponds to a frame extracted from the original video, before being compressed and transmitted. The second picture shows the effect of video compression using the XviD codec with a compression bit rate of 384 Kbps. Finally, the third picture shows the same compressed frame reconstructed at destination after being transmitted through a wireless channel with a bandwidth of 1 Mbps and a BER of 10^{-4}. As it is shown in these pictures, the compression effect is hardly significant, only a little loss of details or a few erroneous pixels could be introduced. The most significant quality degradation occurs when compressed video is transmitted through an erroneous channel.

IV. Conclusions

After evaluating the effects of the wireless channel properties on the quality of transmitted ultrasound video, it follows that the election of the video compression rate depends on the channel BER. Whatever more errors the channel presents, compression bit rate should not be much higher in order to obtain acceptable quality values. Using UDP as transport protocol, better PSNR values than using UDP-Lite have been obtained in all the cases, so considering these results, it is better to reject erroneous frames, replacing them by the previous one, instead of introducing frames with errors. However, it is necessary to indicate that results obtained in this study correspond to mathematical indices that give a reference about the election of video compression parameters in a wireless channel transmission. At the moment, a qualitative analysis of the videos by cardiologists is being carried out, and how PSNR values obtained in this study are related to video quality for clinical use is being evaluated.

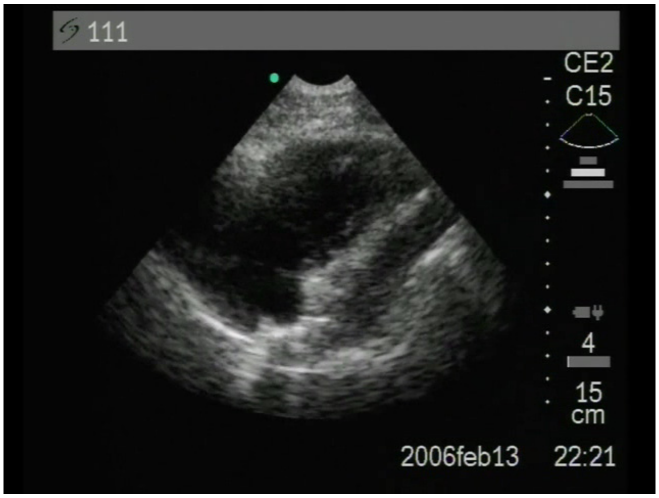

Fig. 4. Source video frame.

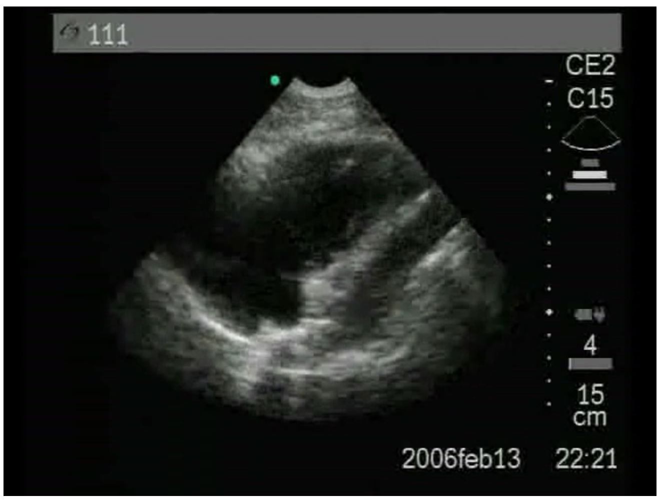

Fig. 5. Reconstructed compressed frame using XviD codec.

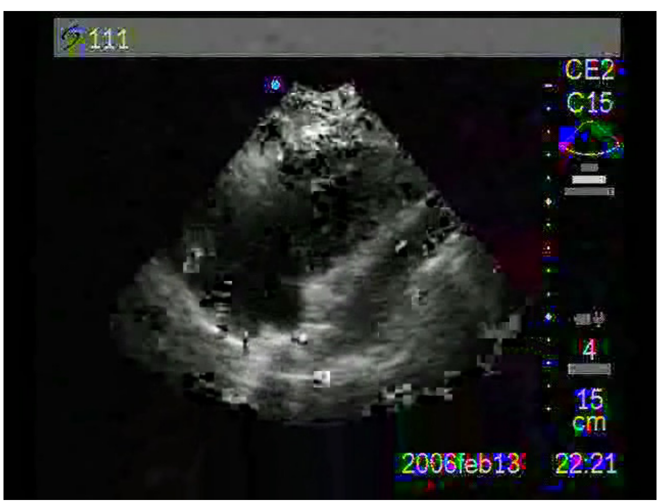

Fig.6. Reconstructed compressed frame after transmission through an erroneous wireless channel.

REFERENCES

[1] S. B. Freedman, *Direct transmission of electrocardiograms to a mobile phone for management of a patient with acute myocardial infarction*, Journal of Telemedicine and Telecare, 1999; Vol. 5: pp. 67-69.

[2] D. Shanit, R. A. Greenbaum, *Towards a comprehensive telecardiology monitoring centre for community-based services*, Journal of Telemedicine and Telecare, 1997; Vol. 3: pp. 60-62.

[3] G. Molinari, G. Reboa, M. Frascio, M. Leoncini, A. Rolandi, C. Balzan, A. Barsotti, *The role of telecardiology in supporting the decision-making process of general practitioners during the management of patients with suspected cardiac events*, Journal of Telemedicine and Telecare, 2002; Vol. 8: pp. 97-101.

[4] Postel, J., *User Datagram Protocol, RFC 768*, USC/Information Sciences Institute, August 1980. Available: http://www.ietf.org/rfc/rfc768.txt

[5] Lars-Ake Larzon, Mikael Degermark, Stephen Pink, Lars-Erik Jonsson, Godred Fairhurst, *The Lightweight User Datagram Protocol (UDP-Lite)*, Internet proposed standard RFC 3828, July 2004. Available: http://www.rfc-archive.org/getrfc.php?rfc=3828

[6] F. Y. Chan, A. Taylor, B. Soong, B. Martin, J. Clark, P Timothy, A. Lee-Tannock, L. Begg, R. Cincotta, R. Wootton, *Randomized comparison of the quality of realtime fetal ultrasound images transmitted by ISDN and IP videoconferencing*, Journal of Telemedicine and Telecare, 2002; 8: 91-96.

[7] Sun K. Yoo, D. K. Kim, S. M. Jung, E-K Kim, J. S. Lim, J. H. Kim, *Performance of a Web-based, realtime, tele-ultrasound consultation system over high-speed commercial telecommunication lines*, Journal of Telemedicine and Telecare, 2004; 10: 175-179.

[8] *Home of the XviD codec*. Available: http://www.xvid.org

[9] Seeling, P.; Reisslein, M.; Fitzek, F.H.P.; Hendrata, S.; *Video quality evaluation for wireless transmission with robust header compression*, Information, Communications and Signal Processing, 2003 and the Fourth Pacific Rim Conference on Multimedia. Proceedings of the 2003 Joint Conference of the Fourth International Conference on Volume 3, 15-18 Dec. 2003 pp. 1346 - 1350 vol.3.

[10] J. P. Ebert and A. Willig. *A Gilbert-Elliot Bit Error Model and the Efficient Use in Packet Level Simulation*. Technical University Berlin. Telecommunication Networks Group. Berlin, March 1999.