# Compressed Medical Image Transfer in Frequency Domain

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**Abstract**

A common approach to the medical image compression algorithm begins by separating the region of interests from the background of the medical images and then lossless and lossy compression schemes are applied on the ROI part and background respectively. The compressed files (ROI and background) are now transmitted through different media of communications (local host, Intranet and Internet) between the server and clients. In this work, a medical image transfer coding scheme based on lossless Haar wavelet transforms method is proposed. The test results have indicated that the performance of the proposed medical image transfer coding via Intranet is much better than via Internet in terms of transferring time, while the quality of the reconstructed medical image remains constant despite the medium of communication. For best adopted parameters, a compressed medical image file (760 KB → 19.38 KB) is transmitted through Internet (bandwidth= 1024 kbps) with transfer time = 0.156 s while the uncompressed file is sent with transfer time = 6.192 s.

**Keywords:** Haar Wavelet, Medical Image Compression, Region of Interest Coding, Adaptive Quantization.

## 1. INTRODUCTION

In recent years, advances in information technology and telecommunications have played a crucial role as catalysts for significant developments in the sector of healthcare. These technological advances have played a very strong role in the field of medical imaging. The number of digital medical images has increased rapidly on the Internet. The necessity of fast and secure diagnosis is vital in the medical world.

Nowadays, the transmission of images has become routine, and it is imperative to find an efficient form by which to transmit them over the Internet or Intranet. To this end, image compression is an important research issue. For instance, in medical image compression applications, diagnosis is effective only when compression techniques preserve all the relevant and important image information needed. This is the case with lossless compression techniques. Lossy compression techniques, on the other hand, are more efficient in terms of storage and transmission needs but there is no warranty that they can preserve the characteristics needed in medical image processing and diagnosis. In this latter case, of lossy compression, image characteristics are usually preserved in the coefficients of the domain space in which the original image is transformed. That is, for instance, in the DWT based medical image compression, the wavelet coefficients keep all the information needed for reconstructing the medical image [1]. Several lossless and lossy techniques for the compression of the medical image data have been proposed [2-4]. Since there is a trade-off between reconstructed image quality and achieved compression ratio, an optimum compression ratio is important. [5]. Several studies have focused on different quality levels for medical applications and a good survey on lossless compression of a region of interest can be found in [6]. The general theme is that diagnostically important regions must be preserved, whereas the rest of the image is only important in a contextual sense, helping the viewer to observe the ROI within the image [7-8]. A lossless image compression over lossy packet networks which is robust in an ATM (Asynchronous Transfer Mode) environment to packet loss and to non-sequential packet receipt is presented in [9]. A context-based and regions of interest (ROI) based approach to compress medical images in particular vascular images is implemented [10], where a high spatial resolution and contrast sensitivity is required in areas such as stenosis. A comparative analysis of image compression techniques is proposed [11-12] which is a framework for ROI based compression of medical images using wavelet based compression techniques (i.e. JPEG2000 and SPIHT). In [13] techniques for determining and extracting the ROI of an MRI brain image are presented.

Figure (1) presents general diagrams of the medical image transfer between the server and the clients in any healthcare centers. The process may include communicating the medical image data from the server to the client at the desired compression level in response to the client's request for the image data [14-15].

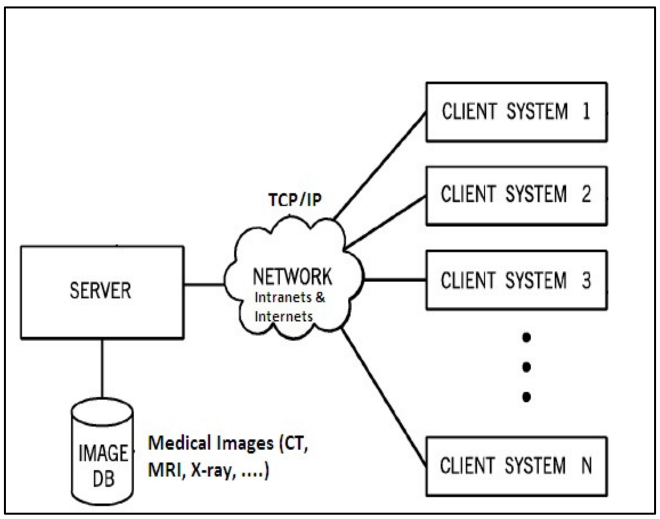


**FIGURE 1:** Medical image data transfer diagram.

The paper is organized as follows: in section 2, an outline framework of medical image transfer is given. Section 3 is a review of the wavelet transform and the description with perfect reconstruction of the selected ROI's. The section also gives information on the quantization and coding of the coefficients. Section 4 gives the results obtained with the proposed method and compares it in both Intranet and Internet. Finally, conclusions are drawn in section 5.

## 2. MEDICAL IMAGE TRANSFER FRAMEWORK

**Server side:**

1. Input uncompressed medical image.
2. Coding process
   a. Color space conversion RGB to YCbCr.
   b. Apply forward wavelet transform.
   c. Select ROI and indicate a set of coefficients which is sufficient for lossless ROI reconstruction.
   d. Perform adaptive quantization on ROI and uniform quantization on background.

e. Encode the resulting coefficients stream by entropy shift coding algorithm.

**Transmission side:**

3. Guarantee network connection (Intranet or Internet).
4. Transmit compressed image data for both (ROI and Background) through socket interface.

**Client side:**

5. Decoding process
   a. Apply inverse entropy shift algorithm.
   b. Perform inverse quantization.
   c. Apply inverse wavelet transform.
   d. Inverse color conversion YCbCr to RGB.
6. Output compressed medical image.

The performance test evaluation is conducted in both Intranet and Internet according to the quality measure PSNR and for different network bandwidth. The transferring time is also determined between server and clients.

## 3. LOSSY AND LOSSLESS (ROI) CODING

Firstly, the medical image is divided into two parts. The RoI is selected using cropping algorithm which is using two points ((x1,y1) as starting point, (y1,y2) as ending point) to create a rectangle of a given region in the image with a variable block size ((20x20), (40,40), etc.). The remaining part of the image (background) is separately coded. The steps of the coding process at the server side for both parts consist of four stages.

### 3.1 Forward Color Space Conversion

This stage converts pixels color representation from RGB to YCbCr color space data. Then, (Cb, Cr) bands are downsampled by (2) to be at lower resolution, the brightness (luma) information is preserved.

### 3.2 Forward Wavelet Transformation

The filter used in this research to apply wavelet transform is the reversible transform (Haar Wavelet). This transform can be used for lossy and lossless coding. Unlike conventional transforms, wavelet decomposition produces a family of hierarchically organized decompositions. The selection of a suitable level for the hierarchy depends on signal nature and experience.

### 3.3 Forward Quantization

The retained (i.e., details) coefficients obtained by wavelet transformation must be quantized for the purpose of compression. The luminance component (Y) requires a small quantization step, while Cb and Cr can be quantized by a larger quantization step. The result of this step is a set of quantization indices that consists of a large sequence of zeros, especially the quantization indices of (HL, LH, HH) subbands.

#### 3.3.1 ROI Quasi Quantization

Since the RoI is the most important part of the image for medical diagnostic purposes, therefore this part must be coded with a non lossy compression algorithm. In this research, the quasi lossless compression algorithm is used by tuning quantization parameters (Q_Y, Q_Cb, Q_Cr) for different wavelet bands (LL, HL, LH and HH). The quasi-lossless compression comes to a high speed. The quality of the reconstruction image under the quasi-lossless algorithm must remain with a higher compression ratio. In figure (2) the effect of different quantization steps according to the Y and Cb,Cr channels is shown.

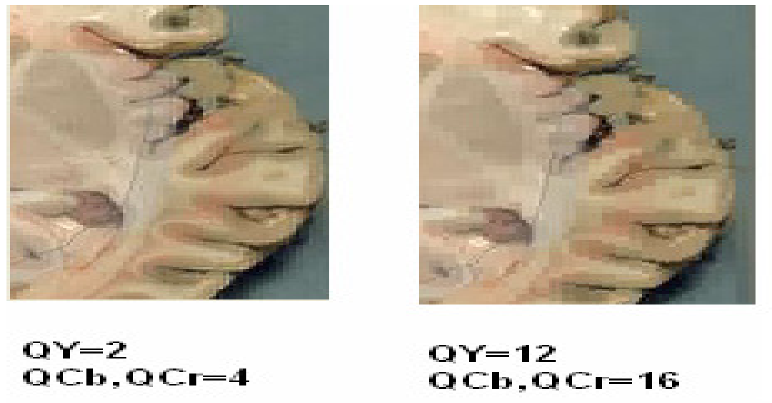


**FIGURE 2:** Effect of quasi lossless quantization.

### 3.3.2 Background Uniform Quantization

The background of the medical image has not had a considerable effect of medical diagnostic. For this reason, this part is compressed by using lossy compression technique. This technique needs uniform quantization steps by dividing QY and QCb and QCr channels by the same number of steps. Figure (3) shows the effect of ROI and background quantization steps.

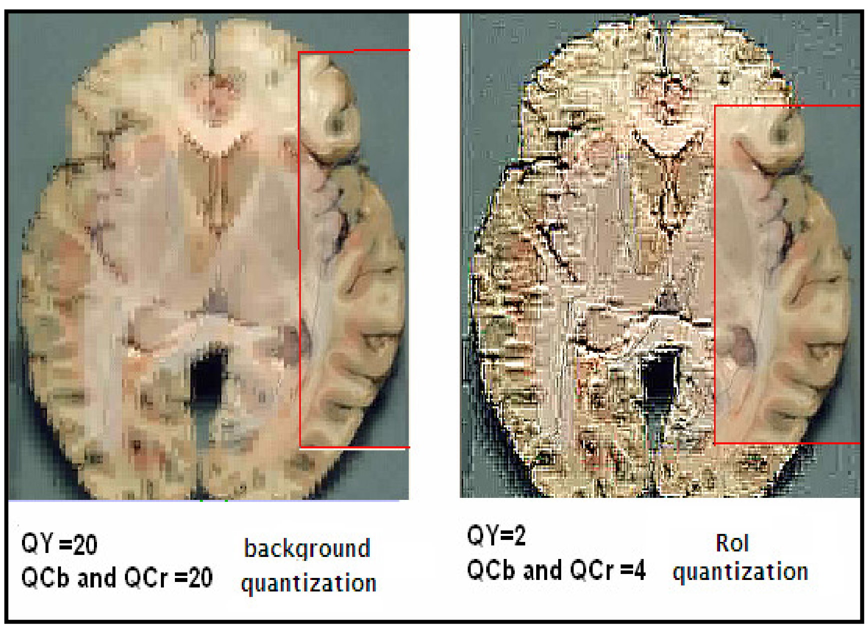


**FIGURE 3:** Effect of lossy and quasi lossless quantization.

### 3.4 Forward Color Space Conversion

After performing the quasi and uniform quantization on the subbands of the image (RoI and Background), the integer indices produced by the quantizer are entropy-encoded by the optimized variable encoder, which is developed in this work. This encoder is considered as a variable length encoder because it gives a small number of bits (short codewords) to represent the small numbers when they mostly occur and a larger number of bits (long codewords) to represent the less probable large numbers. The optimized (variable encoder) algorithm consists of two stages: optimizer and encoder. This algorithm is separately applied on the RoI and the background parts. The following pseudo code presents the shift encoder algorithms step.

Step1: Set Coef = positive wavelet coefficient
Step2: Find MAX(Coef)
Step3: Compute the number of bit to
represent MAX{Coef} = n
Step4: Compute the histogram of Coef = Hist{Coef}
Step5: Optimizer
Step6: Register Optimalm , n+1
Step7: Encoder
Step8: Output Coeff.

## 4. EXPERIMENTAL RESULTS

The results obtained and presented in this section are those of the tests conducted on different types of medical image samples. Normally, the medical image is taken by many medical devices (such as Dicom, CT, MRI, etc.). In this research, the test images are obtained from medical archiving systems through the Internet (Brain (192 KB), Cardiopulmonary Vasculature (768 KB)) MRI images.

The adopted test strategy was based on a determination of the effects of the involved coding parameters (no. of wavelet pass, quantization steps (QY,QCb,r), Internet or Intranet bandwidth) on compression factor C.F, transfer time and fidelity measure PSNR. The value of each coding parameter which led to the best coding results was used during the tests to investigate the effects of other coding parameters.

### 4.1 Intranet Test

In this part, the tests are performed via the Intranet with fixed speed (transfer rate) = 54 Mbps. Tables (1) and (2) show the test results of lossless ROI coding applied on the colorized 'brain' and 'Cardiopulmonary' image respectively, when the quantization parameters are varied for the same number of passes.

| **ROI block size (KB)** | **Transfer time (ms) before compression** | **Transfer time (ms) after compression** | **PSNR in dB** |
|---|---|---|---|
| 80x80 **(18.8→1.13)** | 2.46 | 0.406 | 34.92 |
| 120x120 **(42.2→2.4)** | 10.87 | 0.421 | 34.83 |
| 160x160 **(75→4.10)** | 41.43 | 0.66 | 34.12 |
| 200x200 **(117.18→6.42)** | 45.57 | 0.703 | 33.7 |

**TABLE 1:** PSNR and transfer time for lossless ROI
(QY=2, QC=4, alpha=0.1 and No. pass= 2, 'brain.bmp').

| ROI block size (KB) | Transfer time (ms) before compression | Transfer time (ms) after compression | PSNR in dB |
|---|---|---|---|
| 100x100 (29.3→0.66) | 2.55 | 0.407 | 34.92 |
| 200x200 (117→2.43) | 8.45 | 0.42 | 33.36 |
| 300x300 (263→5.72) | 26.34 | 0.625 | 32.1 |
| 400x400 (468→9.48) | 62.79 | 0.905 | 32.9 |

**TABLE 2:** PSNR and transfer time for lossless RoI
(QY=2, QC=4, alpha=0.1 and No. pass= 2, 'Cardiopulmonary.bmp').

To assess the performance tests of proposed scheme via the Intranet, the transfer time of the ROI part between the server and the clients is determined for different sizes of ROIs. In figure (4), the transfer time before and after compression is shown for different size of ROIs. The parameters are shown according to the table (1).

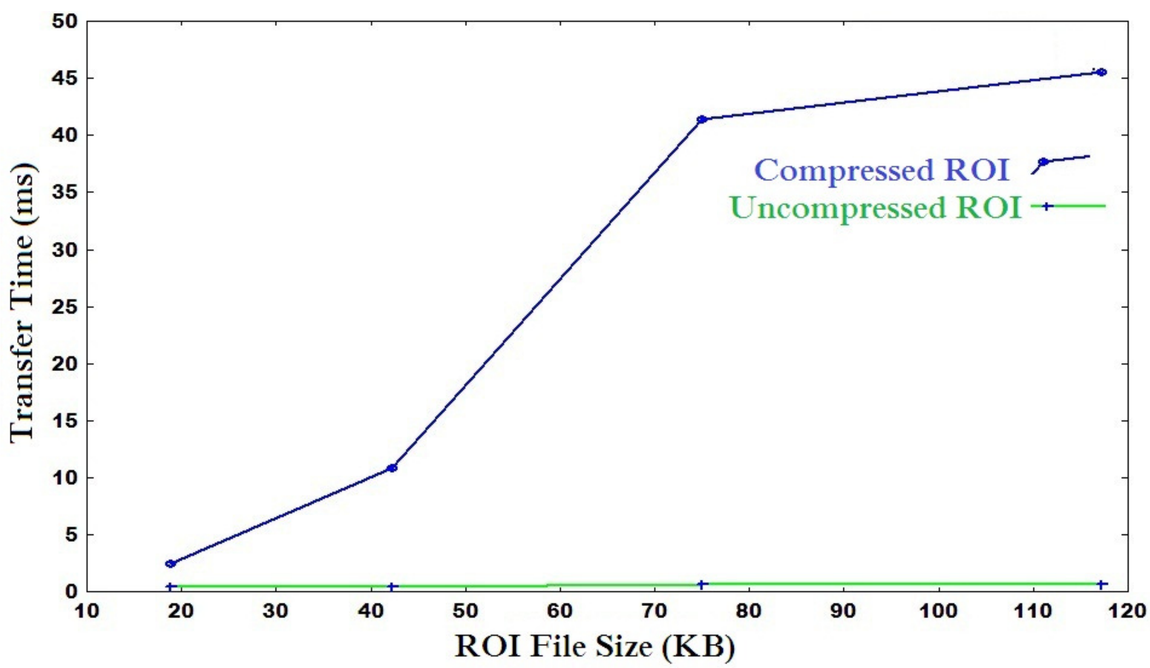


**FIGURE 4:** Transfer time versus RoI file size.

### 4.2 Internet Test

In Internet, the conducted tests are performed using the Internet with a dynamic range of bandwidth speed varied from 128 Kbps to 1024 Kbps for upload and download.

To evaluate the performance of the proposed method tested on the Internet, the transfer time of the ROI part for different values of bandwidth between the server and the clients is determined for different sizes of ROIs. In figure (5), the transfer time versus bandwidth rates before compression is shown for different sizes of ROIs.

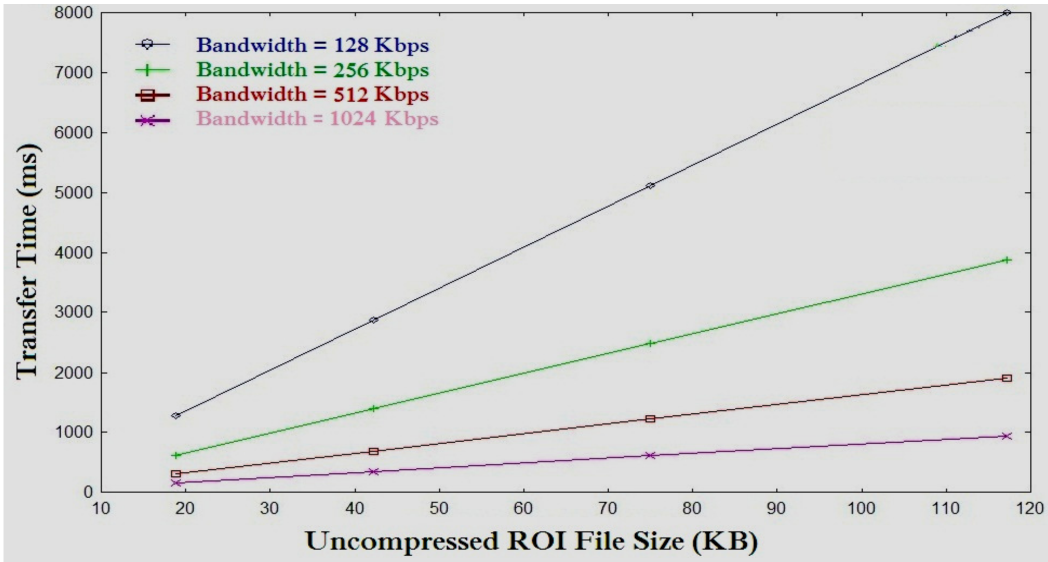


**FIGURE 5:** Uncompressed ROI file transfer time for different bandwidth.

In figure (6), the transfer time versus bandwidth rates after compression is shown for different sizes of ROIs. To make a difference between compressed and decompressed total file size (ROI and background) in terms of transfer time for different bandwidth rates, figure (7) shows the test results of Brain color image.

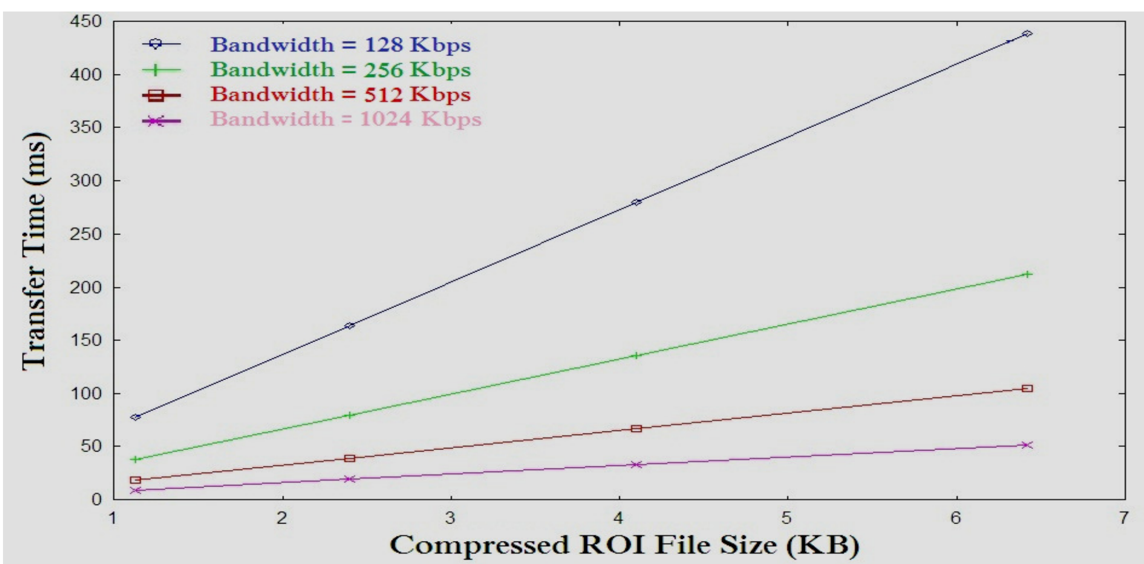


**FIGURE 6:** Compressed ROI file transfer time for different bandwidth.

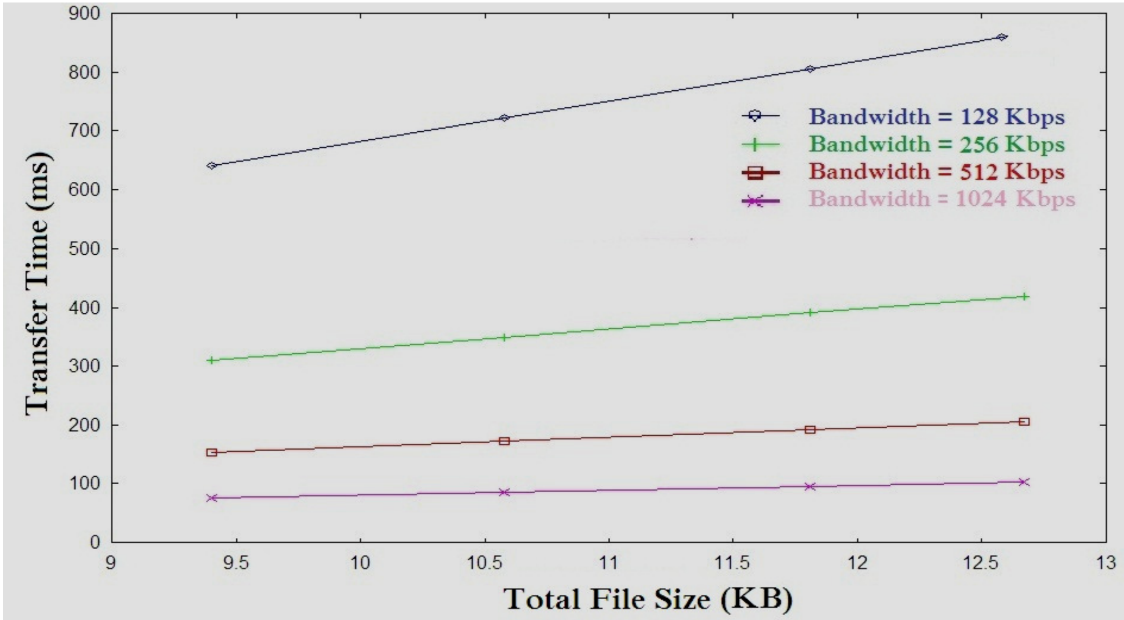


**FIGURE 7:** Compressed file transfer time for different bandwidths.

The same tests as presented in figures (6) and (7) have been performed for larger medical image file size ('Cardiopulmonary.bmp'=768 KB). Another test is performed on a very large color image encoding with RGB system (2.59 MB). The transfer time is calculated for different bandwidth rates as follows:

128 kbps → 3.50 minutes : 256 kbps → 1.74 minutes
512 kbps → 0.83 minutes : 1024 kbps → 0.41 minutes

## 5. CONCLUSIONS

The well-known wavelet transform and variable entropy coding have been used to allow transmission of a medical image with perfect reconstruction of selected ROIs in the image. The proposed scheme calculates a mask which specifies which coefficients are needed for a certain region rather than another to obtain perfect diagnoses of a disease. In this research, the quasi lossless image compression algorithm has been designed and implemented to encode the ROI, while the lossy compression algorithm is used to encode the background of the image. The algorithms are tested in both Intranet and Internet to assess the performance of the proposed scheme.

1. The intranet test results with a fixed bandwidth for both ROI and background have reflected the following:

a. The transferring time before and after compression is decreasing depending on the ROI block size.

b. The intranet communication does not affect the PSNR.

2. The internet test results with a dynamic range of bandwidth rate for both ROI and background have reflected the following:

a. The transferring time before and after compression is decreasing depending on the ROI block size and the bandwidth rates.

b. The larger medical image file size led to larger transferring time when the ROI block size = 200x200.

- Uncompressed file size = 192 KB → transferring time = 1548.1 ms for bandwidth=1024 kbps.
- Compressed file size = 12.67 KB → transferring time = 102.56 ms for bandwidth=1024 kbps.
- Uncompressed file size = 768 KB → transferring time = 6192.3 ms for bandwidth=1024 kbps.
- Compressed file size = 19.38 KB → transferring time = 156.26 ms for bandwidth=1024 kbps.

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