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RELIABLE TRANSMISSION OF MEDICAL IMAGES

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Abstract

Transmission of large volumes of image data via limited spectrum/ bandwidth is a challenge, therefore data needs to be compressed at the transmission end and expanded at the receiver. This compression and expansion may lead to distortion which will hinder the smooth operation of the system. With wireless communication the situation becomes even worse due to noise while traversing. Random bit error or packet losses introduced by the channel may corrupt the critical information. Reliable Transmission refers to error free transmission. In this work an effort has been made to study the factors influencing reliable transmission of medical images via wireless networks and possible solutions to overcome the challenges. Reliability of data transmission over wireless channels can be increased by using channel coding before transmission. 1/2 TC and 3/4 LDPC can be used in case of lower compression ratio and 1/3 TC and 2/3 LDPC codes can be used in case the image is compressed at higher CR.

Keywords: Reliability, Random bit error, Bandwidth.

Introduction

Medical images obtained from different imaging modalities are sent to PACS for storage, archival and transmission. Sharing of the images within the hospital or imaging center is carried out using Local Area Network (LAN) and with the improvement in Internet/Wireless Communication, today imaging data can be accessed at any time across the world for faster diagnosis and research purpose.

With the ever increasing image volume, a cost of owning and operating the on- site storage remains high. Also issues like data migration or data sharing across the departments may require PACS integration

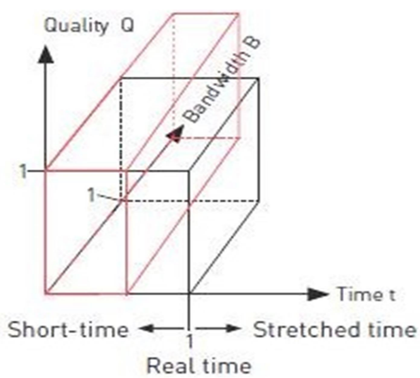

Fig. 1. Transmission Theorem Ideal Case I = B · t · Q = 1

and at times upgradation which is a costly job. Considering the advantages of web-based applications, Hospitals are looking forward to store medical images in cloud.

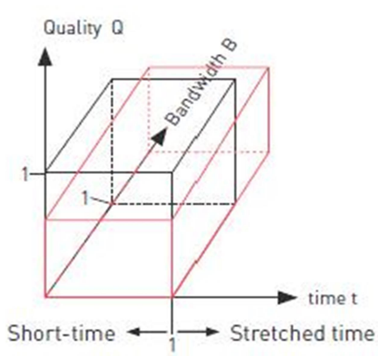

Fig. 2. Short – Time Transmission with Increased Bandwidth

The advantages of web-based applications are: Ease of accessibility, connect from anywhere in the world, Time saving, Efficient search of medical data, High level security, High level interactivity among health care professionals, Availability of large database, Unlimited access, Improved patient care and Tele radiology services.

Design Considerations for Transmission of Medical Images

While transmitting the medical images to and from the cloud, the following parameters are to be considered, Bandwidth (B), Transmission Time (t), Signal –to- Noise Ratio (quality factor Q) and interferences.

According to transmission theorem, in an ideal case quality Q =1 (error free) where a given data volume I is to be transmitted via radio channel with bandwidth B within time t, the relationship between the three is given by equation (1) and can be graphically represented using cuboids with Q, B and t as dimensions (Fig. 1) [1].

$$I = B \cdot t \cdot Q = 1 \quad (1)$$

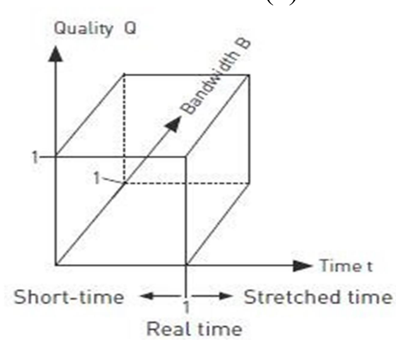

Fig. 3. Decrease in Quality due to Increased Bandwidth

Case 1: If the information is to be transmitted over a short period of time, then bandwidth is to be increased (Fig 2).

$$I = B \cdot t \quad (2)$$

Case 2: When the channel bandwidth is increased, signal-to-noise ratio (quality factor Q) decreases due to arbitrary interferences (Fig3). This is due to the equation (3)

$$Kq = Q \cdot B \cdot t \quad (3)$$

Case 3: In order to avoid arbitrary interferences and maintain signal-to-noise ratio (quality factor Q = 1) the information volume, bandwidth and transmission time must be increased (Fig. 4).

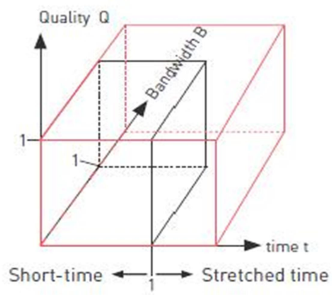

Fig. 4. Increase in Information Volume, Bandwidth and time

Challenges of Wireless Transmission and Possible Solutions

Wireless transmission is prone to path loss, fading, co-channel interference, and noise disturbances due to weather, other wireless devices, or obstructions like wall, which may lead to reception of erroneous packets. In order to protect image quality, reduce transmission time and avoid retransmission, error tolerance is very important. Many techniques are available to tolerate error and reduce bit rate, while achieving higher image quality. Error Control Codes (ECC) helps in detecting errors in transmitted data and has the ability to correct these errors [68]. The choice of best ECC is dependent on parameters such as code rate, code gain, BER, maximum block length and decoding complexity. Table1. shows the various error correcting codes for next generation mobile networks. Many error correction codes have been presented in the past but in recent years two classes of codes have proved themselves as the best candidates to solve the problem, namely Turbo Codes and Low Density Parity Check (LDPC) Codes.

Table 1 - Error Correcting Codes for different Generation Mobile Networks

Parameters/ Networks	2G	3G	4G and beyond
Error Correcting Codes	RS, BCH Codes	Turbo Codes	LDPC Codes
Code Rate	Low 1/6, 1/4	Moderate 1/3, 1/2	High 2/3, 3/4
BER	Poor 10^{-3}	Better 10^{-6}	Best 10^{-8}
Decoding Complexity	Moderate	High	Low

Turbo Codes

Turbo coding is a very powerful error correction coding technique which was introduced by Berrou in 1993. Since then it has made a tremendous impact on channel coding. By achieving near Shannon limit error correction using simple component codes and large interleavers it has outperformed all the previously known coding schemes [2].

The characteristic features of turbo codes are iterative decoding mechanism, recursive systematic encoders and interleavers. Turbo codes enable reliable communication over power constrained communication channels at close to Shannon's limit.

Turbo codes consist of two binary recursive systematic convolutional (RSC) encoders concatenated in a parallel fashion by interleaver (Fig5). The information bits are encoded by both encoders. The first encoder operates on the input bits in their original order, while the second encoder operates on the input bits as permuted by the interleaver. Depending on the code rate desired, the parity bits from the two constituent encoders are punctured before transmission. For example, a turbo encoder of rate 1/3 means all parity bits are transmitted, whereas, for a rate 1/2 turbo code, the parity bits from the constituent codes are punctured alternately.

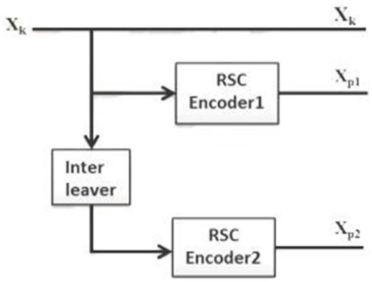

Fig. 5. Turbo Encoder

The role of an interleaver is to construct a long block code from small memory convolutional codes, as long codes can approach the Shannon capacity limit.

Turbo codes are included in Third generation (3G) wireless standards and are widely used in Digital Audio and Video Broadcasting (DVB) and wireless local loop (WLL) for high speed data transmission over wireless channels

Lower Density Parity Check codes (LDPC)

LDPC codes are linear block error correction codes which are also known as Gallager codes. When the block length is too large and the computational codes. hardware implementation of LDPC codes is easy. LDPC codes are used in number of applications such as 4G, optical communication, satellite communication, and DSL (Digital Subscriber Loop), DVB-S2 (Digital Video Broadcasting), and WiMAX [3].

Reliable Transmission of Medical Images

Reliability is obtained at the cost of code rate. Taking specific case of 3G/4G where Turbo codes and LDPC codes are used as Error Control Codes, to obtain higher reliability (that is transmission through noisy conditions) or lower BER, code rate should be high 1/3 in case of Turbo codes and 2/3 in case of LDPC codes.

1/3 implies for every 1 bit of input information to be transmitted, ECC encoder outputs 3 bits. This high redundancy with inbuilt block interleaving ensures low BER at the receiver end.

Since most image formats are based on compression and compressed formats remove redundant information it is very difficult to decode and reconstruct images under error conditions while preserving acceptable viewing quality. Lower CR reduces the code rate requirement from 1/3 to 1/2 in case of Turbo codes and from 2/3 to 3/4 in case of LDPC codes. This can be better explained with the help of an example.

Case 1: Image is transmitted at lower CR say 40%

Lower CR means the information data available is more and higher bandwidth is required for transmission. For reliable transmission, a code rate of 1/2 in case of TC and 3/4 in case of LDPC can be used.

Case 2: Image is transmitted at higher CR say 70%

Higher CR means bandwidth requirement is low. Faster transmission can be obtained using 1/2 or less Turbo codes and 3/4 LDPC codes but this leads to noisy reception/ corruption of the image at the receiver end because when the CR itself is high, there is loss of information due to high CR and when such images are transmitted through noisy channels using ½ TC and ¾ LDPC codes, restoration is not possible by the image processing algorithms. Therefore, in order to obtain higher reliability in case of higher CR, 1/3 TC and 2/3 LDPC codes are used.

Conclusion

Reliability of data transmission over wireless channels can be increased by using channel coding before transmission. 1/2 TC and 3/4 LDPC can be used in case of lower compression ratio and 1/3 TC and 2/3 LDPC codes can be used in case the image is compressed at higher CR.

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