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Cloud enabled fractal based ECG compression in wireless body sensor networks

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HIGHLIGHTS

- We proposed a cloud efficient compression technique suitable for a wireless body sensor network.
- The compression ratio achieved is 40 with Percentage Residual Difference (PRD) of less than 1%.
- The decompression technique is designed to support partial retrieval of ECG data which make it suitable for cloud solutions.
- Better compression ratios compared with other available compression techniques.

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ABSTRACT

E-health applications deal with a huge amount of biological signals such as ECG generated by body sensor networks (BSN). Moreover, many healthcare organizations require access to these records. Therefore, cloud is widely used in healthcare systems to serve as a central service repository. To minimize the traffic going to and coming from cloud ECG compression is one of the proposed solutions to overcome this problem. In this paper, a new fractal based ECG lossy compression technique is proposed. It is found that the ECG signal self-similarity characteristic can be used efficiently to achieve high compression ratios. The proposed technique is based on modifying the popular fractal model to be used in compression in conjunction with the iterated function system. The ECG signal is divided into equal blocks called range blocks. Subsequently, another down-sampled copy of the ECG signal is created which is called domain. For each range block the most similar block in the domain is found. As a result, fractal coefficients (i.e. parameters defining fractal compression model) are calculated and stored inside the compressed file for each ECG signal range block. In order to make our technique cloud friendly, the decompression operation is designed in such a way that allows the user to retrieve part of the file (i.e. ECG segment) without decompressing the whole file. Therefore, the clients do not need to download the full compressed file before they can view the result. The proposed algorithm has been implemented and compared with other existing lossy ECG compression techniques. It is found that the proposed technique can achieve a higher compression ratio of 40 with lower Percentage Residual Difference (PRD) Value less than 1%.

1. Introduction

The use of E-health applications is increasing to a great extent around the globe. Many healthcare organizations such as insurance companies, hospitals, government health sectors and more, require access to patients' information and records including their archived biomedical signals. Therefore, it is required to store patient records in a centralized repository which will provide services to other healthcare organizations to access these records. Accordingly, cloud services can be a solution to serve this purpose [1–4]. As shown in Fig. 1, a cloud healthcare system consists of body sensor nodes which collect patient biological signals (e.g. ElectroCardioGram (ECG), photoplethysmogram (PPG), etc.) and send it to the hospital server. ECG signals require a large amount of storage capability due to its large size. In order to minimize storage requirements ECG compression is implemented in the cloud, to make use of its powerful processing resources, as it is the central point to be accessed by different health agencies. Moreover, in the case of remote patient monitoring systems, body sensor nodes will send collected ECG signals to the patient PDA device and then to cloud, and the compression operation will be implemented inside the cloud. On the other hand, clients trying to access patient records will receive the compressed information and it will be decompressed inside client devices. The proposed decompression algorithm is designed in such a way that allows the user to retrieve part of the compressed file (i.e. ECG segment)

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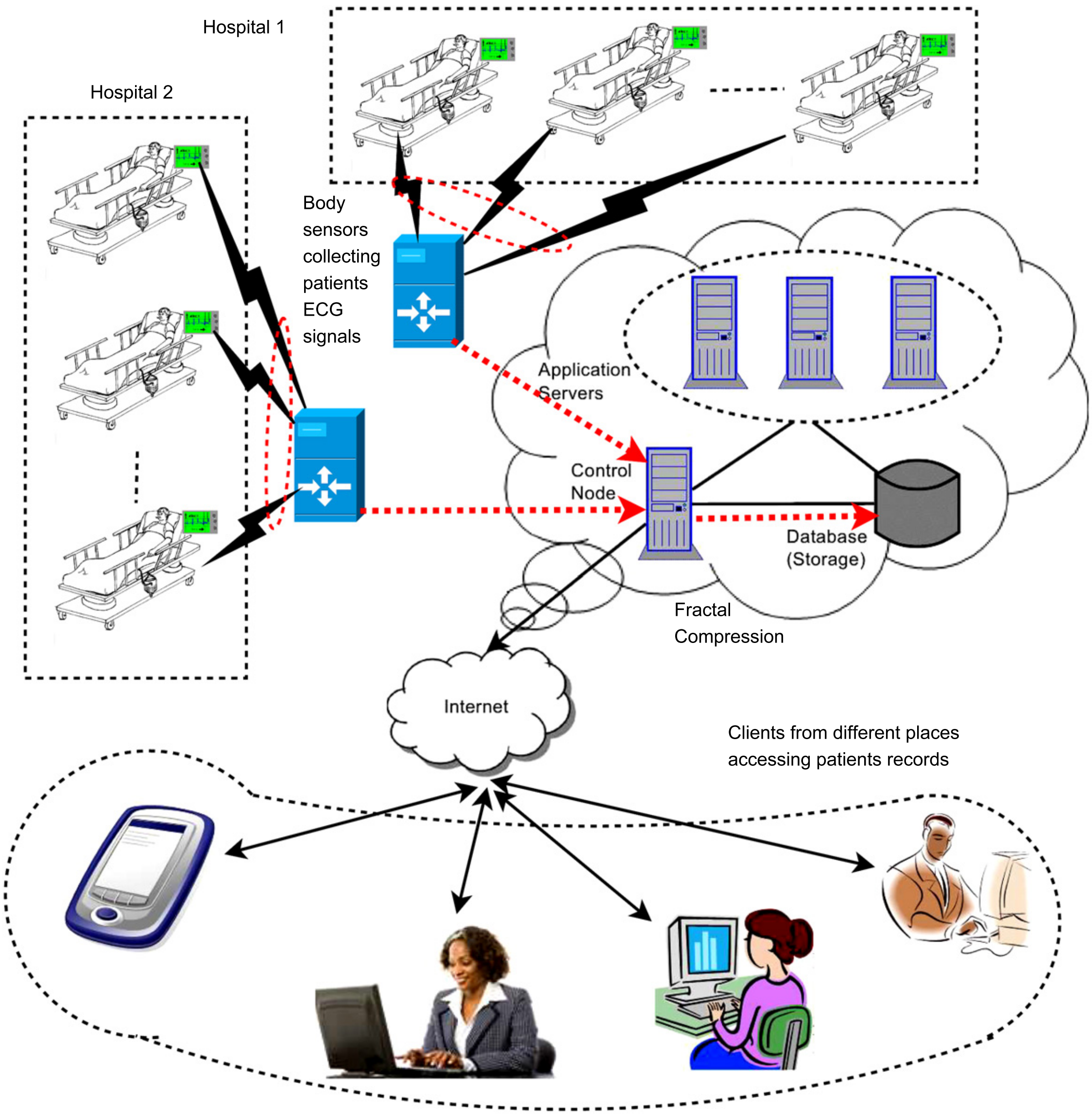

Fig. 1. E-health cloud consists of cloud servers, BSN, hospital servers, and remote patient monitoring sensors. The signals will be transmitted to the cloud; the compression technique is implemented inside the cloud to guarantee faster performance. Different health agencies such as health insurance, doctors, nurses, researchers, and government health sectors can access the cloud and retrieve the desired information in a compressed format, and decompress on their devices after retrieving the information.

without decompressing the whole file. Moreover, the user (such as doctor) can request to receive the compressed ECG signal relevant to a specified period of time, for example, to check the effect of taking medicine at specific time on the patients' ECG. Therefore, the proposed technique can achieve this by sending the required part of the ECG compressed file without adding any more headers or overhead. Finally, on a doctor's device it can decompress the part required without decompressing the whole ECG compressed file. As a result, clients can see the ECG signal as soon as cloud starts to receive ECG from BSN and they do not need to wait for receiving the whole file (which can last for more than 12 h in ECG continuous holter monitoring scenario) before seeing the resultant ECG signal. Therefore, the proposed fractal based compression technique is suitable for hosting and retrieval of compressed ECG data on a cloud. The compression operation is not a real-time operation and therefore, it can be performed offline using the powerful cloud resources. Moreover, as in many cases the doctors would like to check the signal at specific time, the compression technique provides this feature to decompress the file starting from any position but not in a real-time manner.

Generally, compression techniques can be divided into two main categories: lossless and lossy compression. Lossless compression techniques guarantee the full reconstruction of the original signal without any information loss. On the other hand, lossy compression can reconstruct approximated version of the original signal. In lossy compression, it is possible to achieve higher compression ratios with small differences between the original signal and the reconstructed signal. Furthermore, ECG compression techniques can be classified into two major types such as time domain compression techniques [5–7] and transform domain compression techniques [8–10].

Most of the proposed compression techniques are based on R peak detection or other ECG parameter detection. Therefore, they do not provide high performance when applied on abnormal ECG signals since it is extremely complicated to extract ECG signal parameters [11]. The periodic characteristic of the ECG signal and the inter and beat correlation can be powerful features to be used in ECG compression as shown in Fig. 2. Therefore, in this paper, the fractal model is utilized to capture ECG self-similarity characteristics. The fractal techniques have been developed to