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Energy Conservation on EEG Signal Acquisition in WBSN Using a Novel Hybrid CS Technique with Hexagonal Clusters

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Abstract. A novel approach to conserve energy among the electrodes during the EEG signal acquisition in wireless body sensor network is presented in this paper. The proposed work applies a hybrid compressive sensing technique on the optimized hexagonal cluster which holds the electrodes that acquire the EEG signal from the neurons. The hybrid CS on hexagonal cluster has been proved to be efficient in reducing the energy consumption in the network. Further the results are compared to the existing energy conservation methods of hybrid CS on tree structure and hybrid CS on cluster structure methods, where the result reports that the proposed technique outperforms by reducing the energy consumption by about 55% and 25% on an average for varying number of nodes, 47% and 35% for varying field density and 60% and 45% for varying number of projections, for the compression ratios of 10 and 5.

Keywords: Wireless body sensor network, EEG, Energy conservation, Hybrid compressive sensing and hexagonal clustering.

1. Introduction

The Wireless body sensor network computing wearable devices may be embedded inside the body, surface-mounted on the body in a fixed position or may be accompanied devices which humans can carry in different positions, in clothes pockets, by hand or in various bags. The application of WBSNs are expected to appear primarily in the healthcare domain, especially for continuous monitoring and logging vital parameters of patients suffering from chronic diseases such as diabetes, asthma and heart attacks [1]. Further the application of this technology can be found in sports, military, or security domains.

The BSN sensors is used to measure blood glucose, blood pressure, electrocardiography (ECG), electroencephalography (EEG), electromyography (EMG), gyroscope, and pulse oximetry [2]. The most common sensors are ECG sensor which monitors the heart rhythm and the EEG sensor that records the electrical activity of the brain.

This paper discusses about the electroencephalography (EEG) in the wireless body sensor network and its energy conservation methodology during signal acquisition and transmission. EEG was used to be a first-line method of diagnosis for tumors, stroke and other focal brain disorders [3], but this use has decreased with the advent of high-resolution anatomical imaging techniques such as magnetic resonance imaging (MRI) and computed tomography (CT) [4]. Despite limited spatial resolution, EEG continues to be a valuable tool for research and diagnosis, especially when millisecond-range temporal resolution (not possible with CT or MRI) is required [5].

The EEG involves in diagnosing epilepsy, sleep disorders, coma, encephalopathies, and brain death. The Epilepsy monitoring distinguishes epileptic seizures from other types of spells, such as psychogenic non-epileptic seizures, syncope (fainting), sub-cortical movement disorders and migraine variants, and also

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characterizes seizures for the purposes of treatment [6]. Further, the EEG can also be used in intensive care units to monitor non-convulsive seizures/non-convulsive status epileptics, the effect of sedative/anesthesia in patients in medically induced coma (for treatment of refractory seizures or increased intracranial pressure) and the brain damage in conditions such as subarachnoid hemorrhage (currently a research method).

The EEG signal acquisition and transition can be done by implanting the strips and grids of electrodes (or penetrating depth electrodes) under the dura mater, through either a craniotomy or a burr hole. The recording of these signals is referred to as electrocorticography (ECoG), which functions on a different scale of activity than the brain activity recorded from scalp EEG.

Since power consumption in WBSN [7] is found to be an issue, this paper addresses the issue of power consumption among the sensors (electrodes) during the signal acquisition and transmission by implementing a hybrid compressive sensing methodology with hexagonal clustering in wireless body sensor network. The remaining work is organized as follows. Section 2 describes the working of compressive sensing; the experimentation on the proposed work is reported in Section 3and section 4 evaluates the performance.

2. Compressive Sensing

The EEG signal acquisition and transition in wireless body sensor network contributes to majority of energy consumption of the sensors (electrodes). So it has become an important issue to reduce the energy consumption. The reduction in energy consumption can be achieved through the apparent technology of compressive sensing. The CS technology can significantly reduce the amount of data transmission and balance the traffic load in wireless BSN.

This section discusses the working of compressive sensing. The system in Fig. 1 consists of 1 sink node and '*n*' number of sensor nodes which collects the data from the field. If '*m*' denotes a vector of original data having '*n*' elements collected from the sensors, them 'm' can be represented by the product of a vector co-efficient '*v*' and a '*n x n*' transform matrix ' ψ ', as m= ψv. The ψ domain will represent '*m*' as sparse if there are '*k*' non-zero elements in '*v*'. If the value of '*k*' is found to be small then, only a small number of projection of '*m*' will be transmitted to the sink, represented as u= ϕm, where ϕ is a random matrix. Finally, after the transmission, the original data '*m*' can be recovered at the destination by using various recovery algorithms such as orthogonal matching pursuit or l_1-norm minimization.

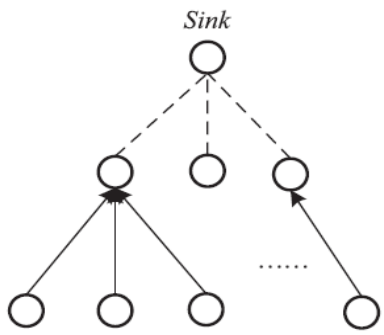


Fig. 1: Pure CS on Tree Structure

The absence of CS increases the number of transmission, since the nodes closer to the destination transmits larger number of packets compared to the other nodes. Whereas, the presence of CS makes every node in the network to transmit '*X*' packets for a set of '*Y*' data items. The proposed hybrid CS approach in [8] [9] were found to be better than the pure CS in reducing the number of transmissions, since only the nodes closer to the sink will perform the CS technique. The latest energy conservation technique implemented the hybrid CS method with clusteration, as shown in Fig. 2. This method was found to be better than the hybrid CS with tree structure, in terms of fault tolerance, traffic and load balancing in the network.

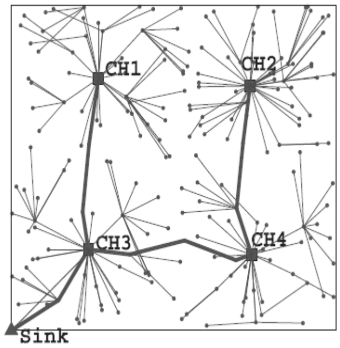


Fig. 2: Hybrid CS in Cluster

In this paper, we propose a optimal hexagonal cluster that uses the hybrid CS to optimize the energy efficiency in EEG signal acquisition, which is explained in detail in the following sections.

3. Experimentation

3.1. Hybrid CS on Hexagonal Cluster

In view of the benefits of the hexagonal cluster, which requires fewer cells has maximum coverage area and reduced number of inter cluster transmission compared to the existing squared cluster, as proved in [10], [11], the proposed work used in hexagonal cluster.

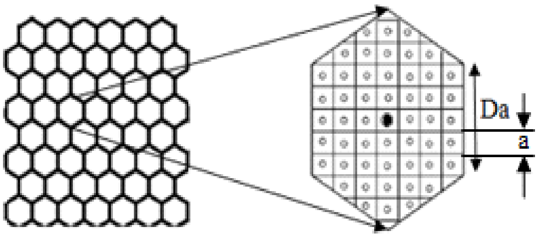


Fig. 3: Hybrid CS on Hexagonal Cluster

Fig. 3 represents a pool of hexagonal clusters, where each and every individual cluster is located with cluster head and the sensor nodes arranged uniformly with the edge length of the cluster has '*D*' and edge length of the inner grid has *'a x a'*. Further, the hexagonal cluster uses the hybrid CS technique were the nodes within the cluster transmit data to the head without CS and the node that forward these data to the sink uses the CS method.

3.2. EEG Signal Acquisition and Electrode Setup in Hexagonal Cluster

This section discuss about the energy efficiency achieved on the EEG signal acquisition generated from the neurons through the electrodes located on the scalp of the head. Fig. 4 denotes the EEG signal acquisition electrodes located within a hexagonal cluster model. This setup makes the signal acquired by the electrode to be processed locally within the cluster by their respective cluster heads. This minimizes the network traffic and the artifacts generated from all the electrodes to a minimal level.

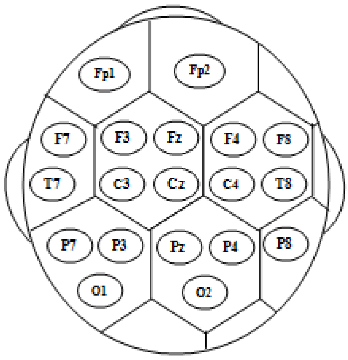


Fig. 4: EEG Signal acquisition electrodes located in a Hexagonal cluster model.

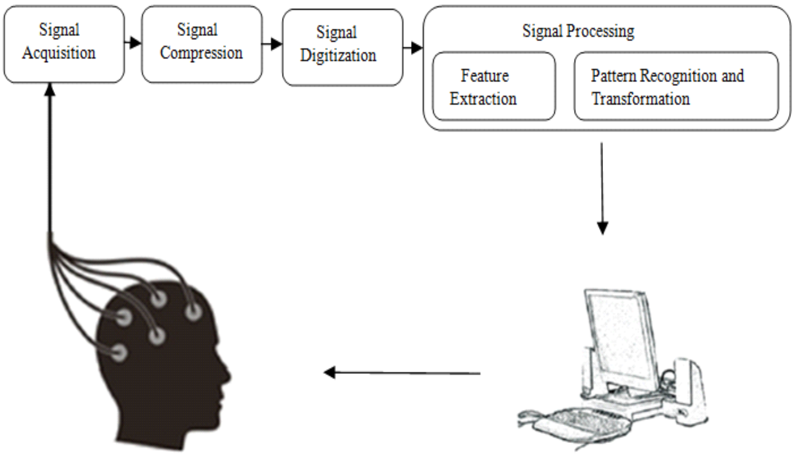
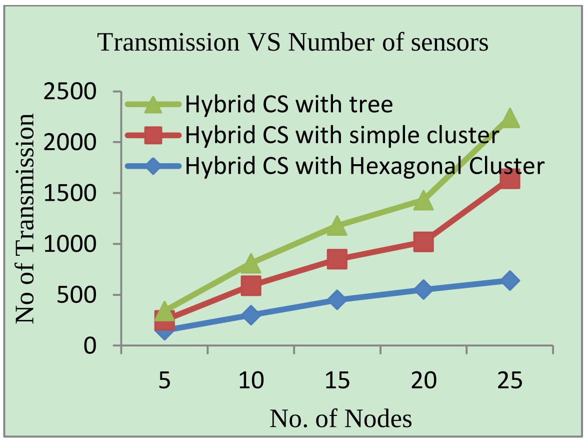


Fig. 5: EEG signal acquisition and Processing system

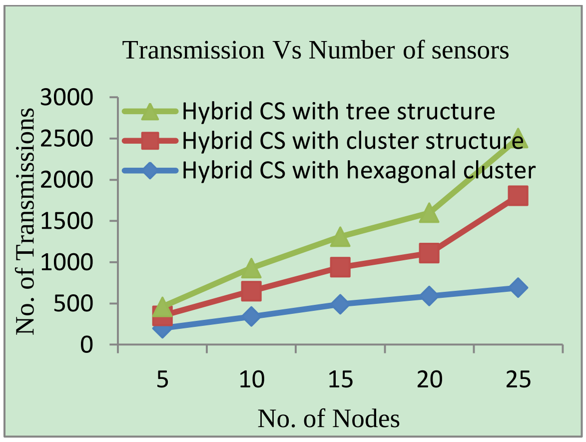
The signal acquisition and processing in WBSN is performed as shown in Fig. 5. The signal acquired from the hexagonally clustered electrode will be compressed using the proposed hybrid compressive sensing method before it undergoes the signal digitization and processing mechanisms where the feature extraction, pattern recognition and the signal transformation process will be performed.

4. Performance Evaluation

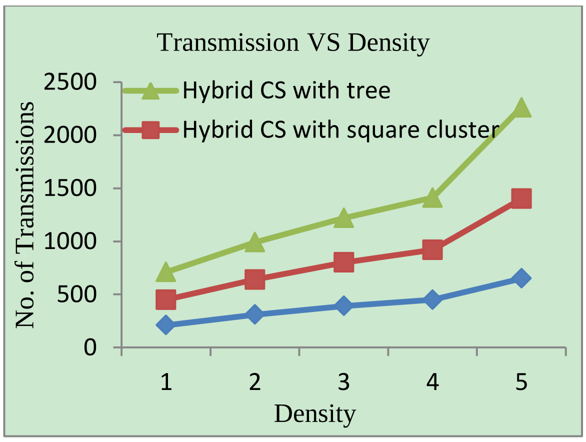
The performance of the proposed hybrid CS with hexagonal cluster is evaluated and compared with the hybrid CS on tree and hybrid CS on simple cluster based data collection methods [12]. The metric used to evaluate the specified performance is, the number of transmissions. The compression ratio 'ψ' is set to 10 and 5 (ψ = N/M, where *N* is the number of nodes and *M* denotes the number of projections taken to transmit the data from the cluster head to the sink).



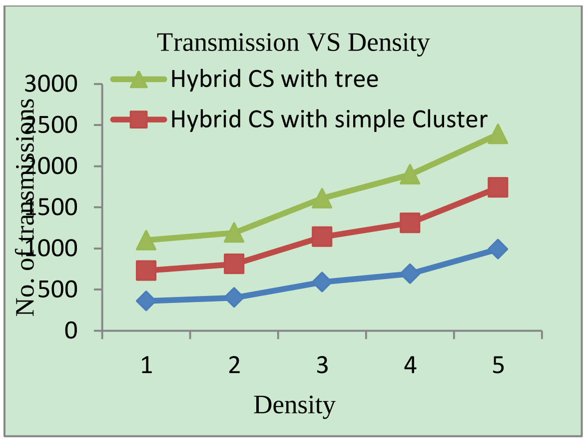
a(i)Transmission for varying no. of nodes with CS ratio 10



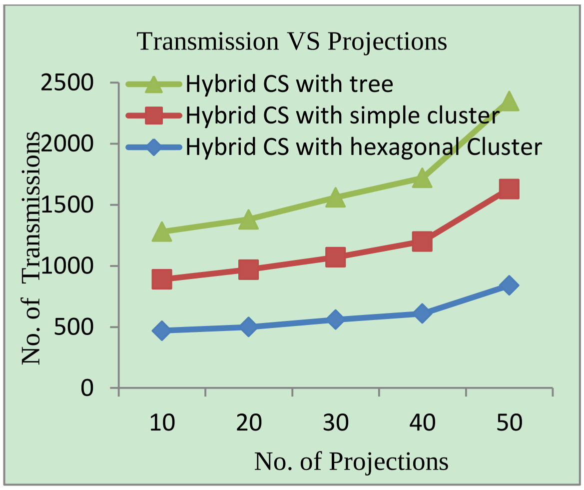
a(ii)Transmission for varying no. of nodes with CS ratio 5



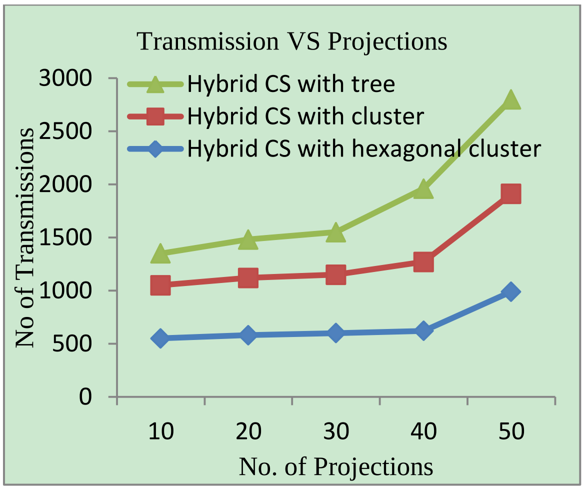
b(i)Transmission for varying density with CS ratio 10



b (ii)Transmission for varying density with CS ratio 5



c (i) Transmission for varing no.of projections with CS ratio 10



c (ii) Transmission for varing no.of projections with CS ratio 5

Fig. 6: Represent the number of transmissions required for varying (a) no. of nodes (b) density (c) no. of projections, for the compressive ratio of 10 and 5.

For 'ψ' being 10, Fig. 6 a(i) reports that the proposed method reduces the number of transmission by about 60 % compared to the hybrid CS with tree and 30 % compared to the hybrid CS with the simple square cluster structure, for varying number of nodes. For 'ψ' being 5, the reduction obtained through the proposed method is found to be about 50 % compared to the hybrid CS with tree and 20 % to hybrid CS with cluster structure. The experimentation performance for varying density in the field reports through Fig. 6 b (i) that the hybrid CS with hexagonal cluster is energy efficient by about 55% and 40% compared to the hybrid CS with tree and simple cluster structure with the compressive ratio of 10. Similarly, for 'ψ' being 5, Fig. 6 b (ii) denotes that the proposed mechanism achieves energy efficiency by about 40% and 35% compared to the hybrid CS with tree and the existing non-optimal cluster structure. Finally, the efficiency and effectiveness of the proposed method has been proved by Fig. 6 c (i) with the energy reduction of about 65% and 50%, and by Fig. 6 c (ii) with reduction by 55% and 40% compared to the existing hybrid CS with tree and cluster structure.

5. Conclusion

The work presented a hybrid compressive sensing technique with the optimized hexagonal cluster structure to reduce the energy consumption by the sensors.

The obtained experimentation results are compared to the hybrid CS with tree structure and hybrid CS with simple cluster structure, which reports that the proposed method reduces the no. of transmissions by about 55% and 25% on an average compared to the hybrid CS with tree and cluster for varying number of nodes. Similarly, for varying field density, the hybrid CS with optimal hexagonal cluster is found to be efficient through the transmission reduction on an average of about 47% and 35% compared to the existing compressive methodologies. For variation with the number of projections, the proposed method reports the achievement of energy efficiency by about 60% and 45% on an average compared to the hybrid CS with tree and cluster structure methods. The entire experimentation is carried out with a compression ratio of 10 and 5.

Finally, the implementation of the hybrid CS with hexagonal cluster will be carried out in future to optimize the WBSN through energy conservation during the EEG signal acquisition and the results will be compared to the existing pure compressive sensing technology used in WBSN.

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