An Efficient Data Aggregation Method in Wireless Sensor Network based on the SVD

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ABSTRCT:

The Wireless Sensor Networks (WSN), consists of thousand small and inexpensive sensing devices (Sensors) with a limited energy resources, memory, computational capability, and communication[1]. In WSN, most of the limited energy will be expended during the communication process, both reception and transmissions[2]. Thus, reducing the amount of energy consumption during the transmission process can increase the WSN lifetime and overall efficiency.

One of the most effective methods of the energy reduction in WSN is to reduce the amount of transmitted data between the sensor nodes and Cluster Heads(CH) as well as the transmitted data from cluster heads to the Base Station(BS) [3, 4]. These data reduction criteria can be accomplished by using data aggregation algorithms in which the data redundancy will be eliminated to reduce the amount of transmission data as well as to improve the energy consumption required for the transmission in WSN. During the data aggregation process, the collected data from the various sensor nodes and cluster heads will be combined to be processed by an efficient algorithm to reduce the possible data redundancy. The elimination of data redundancy will minimize the amount of useful data to be transmission and reduce the overall energy consumption which improves the efficiency and increase the life time of the WSN.

The process of data reduction by eliminating the possible data redundancy to obtain the useful data with the minimum volume would be more effective when the data types are images. Our proposed algorithm will use Singular Value Decomposition (SVD) to extract the important features of the images needed to build the feature vectors. These feature vectors can be used to find the similar images, reduce the redundancy, and create useful images with least volume before they are transmitted to the cluster heads or from cluster to the base station.

Our proposed algorithm will apply SVD on all images that are transmitted from sensor nodes to the CH and use the feature factors obtained from SVD analysis to eliminate the number of similar images in each cluster group and save the energy consumption due to reduction of the transmitted images from CH to the BS. Our algorithm is appropriate for both type of heterogeneous and homogeneous WSN regardless the type of algorithm that is used for the clustering process.
The results of implementation show that the number of transferring images from CH to the BS is reduced about 50 percent in the proposed algorithm. In addition, the comparison of our proposed method with the LEACH algorithm, Figure 4, clearly indicated that our method has a better life time than the LEACH algorithm.

Key Words: WSN, SVD, Lifetime, Sensor, Redundancy, Energy, clustering, Image reduction.

1. INTRODUCTION

Wireless Sensor Networks consist of a large number of sensor nodes, which are distributed in the environment and each of them autonomously, follow a particular purpose by the cooperation of other nodes[5, 6]. Nodes are close together, and each node can communicate with another node and share its information with others. The sensing devices in WSN can be used to collect the environmental information from the sensors and then transmit them to the cluster heads. The collected information received by each CH will be processed and transmitted to the sink or base station to control the environmental conditions, such as moisture, humidity, chemical gas leakage, or dangerous gas distribution in the coal mines[7]. To control the environmental conditions of some designated area in woods, or control the behavior of the wild habitants in the forest, or even monitor the enemy movements in a battle field, we need to have an unlimited energy resource for long life WSN. But due to the limitation of energy resource for each node some measures should be taken to reduce the energy consumption of each sensor node for the information collection and data transmission. There are many techniques that can be used to apply in order to reduce the energy consumption of the WSN [8-10].

Clustering architectures are the most effective algorithm in energy consumption[11]. Clustering is an efficient energy saving approach that can be used to put a group of adjacent sensor nodes under one cluster group and assign a cluster head for the group. All nodes at the same cluster will transmit their data to the cluster head and collected information will be transmitted to the base station.

In clustering network, some nodes are selected as a cluster head to be responsible for the data aggregation from other nodes of the cluster group. The collected data at each cluster head will be transmitted to the sink node or BS[12]. In each cluster most of the aggregated data from the neighboring nodes are usually repetitive, redundant and highly correlated[13]. According to the classification techniques presented in[14] all methods of energy consumption reduction in wireless sensor networks are divided into three general categories:

- Duty-Cycling
- Data-Driven
- Mobility-Based

Unlike other methods, in Data-Driven plans, the collected data by the sensors are considered and processed to obtain the energy reduction during the transmission time from the CH to the BS by one of these two methods [14]:

- Data reduction
- Energy-Efficient data acquisition

It should be considered that the purpose of all these methods is to reduce the energy consumption and consequently to increase the life time of WSN. One of the best solutions to reduce the amount of the transmitted data in WSN is the use of data aggregation techniques. Since the collected data by the sensor are highly correlated, there would be not necessary to transmit the redundant (duplicate) information to the BS [13] because the transmission of the duplicated data to BS leads to the energy lost. The problem of the data redundancy can be considered with special cares when the sensing devices are collecting images rather than other type of data.

In our proposed algorithm, the network is divided into few clusters and in each cluster the data sensed by the sensing devices will be transmitted to their cluster heads. Cluster heads aggregate or receive the data by using proposed algorithm and do not send the duplicate data. By applying the SVD algorithm in each cluster head and creating the feature vectors to be compared to remove the redundancy, duplicated and similar images would be removed and only those images that contain vital information will be transmitted to BS.

2. SINGULAR VALUE DECOMPOSITION (SVD)

Singular Value Decomposition (SVD) is one forms of matrix analysis which leads to a low-dimensional representation of a high dimensional matrix. It can be applied to any matrices of real or complex. Let us have a real matrix P with m rows and n columns but with rank R, where R ≤ n ≤m. Then the matrix P can be decomposed into three matrices of U, Σ, and V [15]:

$$M = U\Sigma V^T = \sum_{i=1}^{n} \sigma_i \, u_i v^T{}_i \quad (1)$$

Where matrix U is an m × m orthogonal matrix, V is an n × n orthogonal matrix, and Σ is an m × n rectangular matrix with non-negative real numbers on the diagonal elements, and V^T called the transpose of V. The diagonal entries $\Sigma_{i,i}$of Σ are known as the singular values of P as following:

$$\Sigma_{i,i} = \text{diag}\,(\sigma_1, \sigma_2, \dots, \sigma_{r+1}, \dots., \sigma_n) \quad (2)$$

Where $\Sigma_{i,i}$ is the n × n elements of the matrix Σ and the rest of its elements are zeroes.

3. PROPOSED ALGORITHM

Our Proposed algorithms can be applied for the cluster-based wireless sensor networks to remove the data redundancy and to prevent the unnecessary data transmissions to prolong the lifetime of the sensor networks.

Our method is designed to identify the similar images in one cluster and to remove the image redundancy before images are transmitted from CH to the BS. To achieve the objective and to obtain an efficient algorithm we have performed the data aggregation locally in CH as well as applied the SVD to the Cluster Heads for the data aggregating. By applying SVD on each cluster we can reduce the number of the sensed images by removing the repetitive images as well as the similar images. Thus, those images that are transmitted from CH to BS by using the proposed algorithms will have the vital information about the environment. It also has the best characteristic of the images located inside the cluster group and suitable for the transmission from CH to BS.

In our proposed algorithm the SVD is applied on each image inside the cluster group and the singular values of each image are stored into a vector called feature vector. The Frobenios Norm can be applied on each feature vector to obtain an efficient algorithm for the comparison. Once, the norms of the feature vectors are calculated and then compared with the Norm of other feature vectors, the redundant elements are detected and then removed, using the best norm approximation. Once the norm of Singular values of two images is the same, or very close to each other as compared with a threshold, one of the images can be removed to decrease the redundancy. By using SVD we have eliminated the similar images and reduced the number images to be transmitted from CH to BS.

For applying proposed algorithm, the following assumptions are made for the WSN.

- The sensors are considered to be fixed sensors.
- The base station has infinite processing energy.
- Sensors are uniformly and randomly distributed in the environment.
- In each round, all nodes send data to the base station.
- All nodes are equipped with the cameras for monitoring a network environment.
- Data of all nodes are image type.
- The structure of the network is clustering

a- Steps of Proposed Algorithm

This algorithm has the following step in each round:

- Clustering

In this step, the nodes are divided into groups called clusters. Each cluster consists of a selected node called cluster head. Clustering

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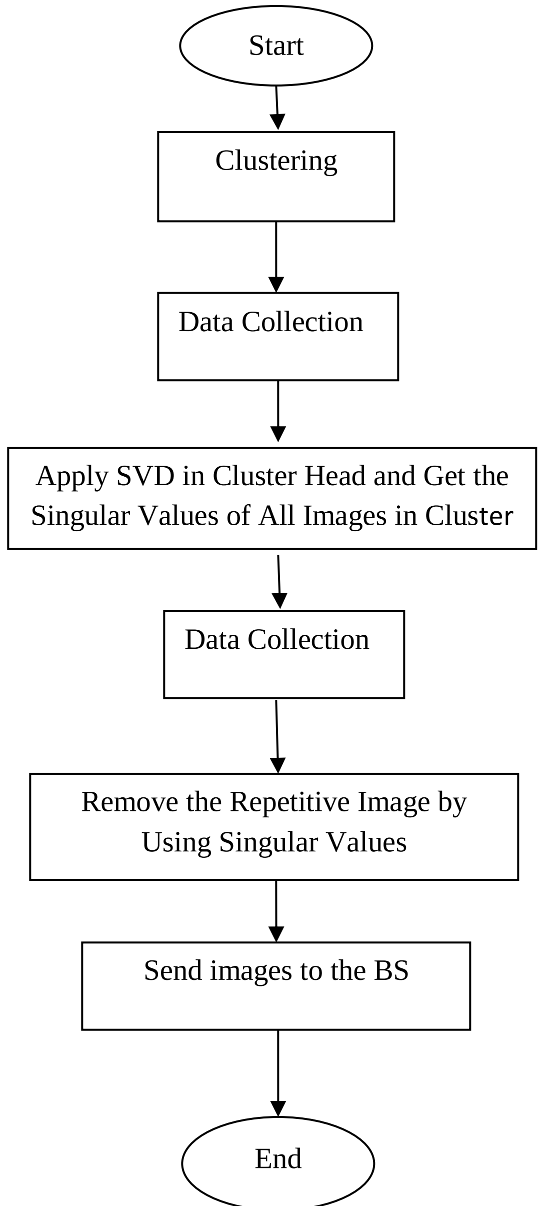

Figure 1: Flowchart of Proposed Algorithm

can be done by any methods of clustering such as, LEACH, HIT, PEGASIS, etc. after choosing cluster heads, nodes become a member of the cluster heads.

- Data collection

In second step, data or sensed images will be transferred unprocessed from normal nodes to the cluster head. It means that images which received from the cameras will be sent to the cluster heads without any processing.

- Apply SVD in cluster head and get Singular Value of all images in the Cluster Head.
- Remove the repetitive image by using the Singular Values of the images in each cluster.

To compare images in the cluster head and to delete the duplicate and similar images we calculate the Frobenios Norm of the Singular values and find the similarity between images in one cluster. In addition, we have used mean and variance to make the feature vector more versatile and strong.

- Send selected images to BS.

Cluster head adds selected images to the sending data queue in order to send it to the base station.

a- Comparing Gray Scale Images

For comparing the gray scale images we do the following stages:

- Applying SVD on images for each cluster and get the Singular Values of all of them.
- Calculate the Singular Values of each image in the cluster.
- Calculate the mean of the norm of the Singular Values of each image.
- For choosing similar images a threshold would be considered and if the norm difference from the previous stage is less than the considered threshold, two images will be considered similar.

b- Comparing Color Scale Images

For color images we have used different comparison method. The colored image consists of three components of red, green and blue. So for comparing images we do the following stages.

- Obtained the Red, Green and Blue components of images.
- Applying SVD on Red, Green and Blue components of images to calculate the Singular Values of Them
- Apply the Frobenios Norm on Singular Values of each color space, Red, Green, and Blue.

- Calculate the mean of the norm of the Singular Values for three color spaces red, green and blue components of each image.

For choosing similar images a threshold would be considered and if the mean difference from the previous stage is less than the considered threshold, two images will be considered similar.

4- SIMULATION

We have applied two scenarios to show the performance of our algorithm over the existing methods. The simulation conditions for the implementation of both methods were intended to be the same, In the first scenario no manner has been applied for data aggregation in CHs and all images that received from clustered nodes will transfer to BS in fact, in first scenario we simulated LEACH algorithm (Low Energy Adaptive Clustering Hierarchy) that has simple algorithm for data aggregation whereas in implementation of second scenario which means proposed algorithm, according to above, SVD was used to eliminate the similar images and implemented as a data aggregation to reduce the amount of data.

For simulating the proposed algorithm and demonstrate its performance , we have used the MATLAB software. In this assumed simulation, 100 nodes in an area of 100 square meters are randomly distributed. The central node location is at the point (50, 50).

Table 2: Network Life Time for two scenarios

	Scenario 2 (Proposed Algorithm)	Scenario 1 (LEACH Algorithm)
First Round Node Dies (FND)	188	99
Last Round Node Dies (LND)	776	659

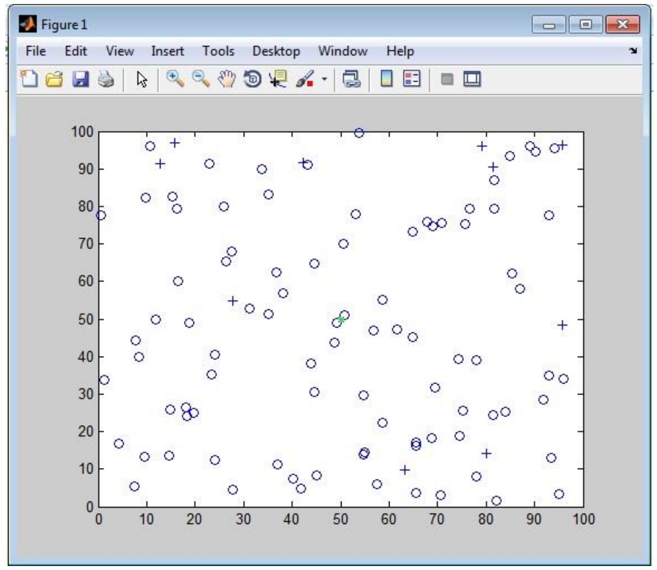

Figure 2 : Distributed randomly 100 Sensor Nodes in a 100×100 meters area

The purpose of the advanced nodes is that the amount of initial energy of them is more than normal nodes. It means that the offered algorithm can be used in both heterogeneous and homogeneous sensor networks. All parameters used for the simulation are provided in Table1.

Table 1: Parameters for Simulation

Parameter	Value
Simulation Area	100 × 100 m2
Number of Nodes	100
Node Deployment	Randomly
Normal Node Initial	200 j
Advanced Node	400 j
threshold	10
Eelec	5×10-8 j
Eamp	1.3×10-15 j

a. Allocating Images to Sensors in the Network

According to positional coordinate of each node, to stimulate the node imaging, an image will be randomly allocated to that node in each round. To do this, the same sensing environment like Figure 3 is considered.

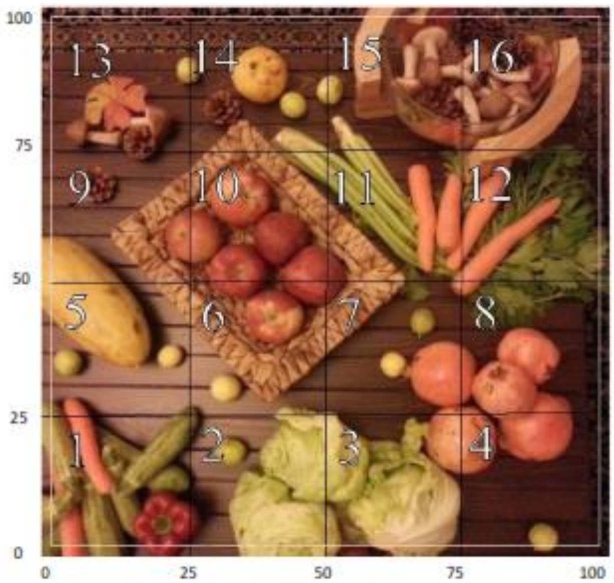

Figure 3 : Sensing Area for Simulation

For allocating appropriate images to the nodes which are distributed in the sensor area, we divide the sensor area to 16 virtual areas like Figure3. Each of the 16 areas will be imaged from various directions and put them in 16 separate groups which are correspondents to the areas. In each round, according to the area where a node is placed, a corresponding group will be selected and an image will be randomly selected from related groups and allocated to the node.

5- ANALYSIS OF ENERGY CONSUPTION

In table 2 the results of simulation of two defined scenarios are compared by using standard network lifetime metrics. First Node Died (FND) and Last Node Died (LND) metrics are used to measure the network lifetime. According to FND standard, the network lifetime is equal to the time or round the first node dies and gets out of the network and according to the LND standard, the network life time is equal to the rounds the last node dies in the network[16]. As can be seen in Table 2, in proposed algorithm in comparison with LEACH algorithm which is simulated in first scenario, the network lifetime is increased about 50 percent.

Due to elimination of redundant images via SVD and reduction of energy consumption subsequently, the network lifetime would be increased in proposed algorithm. In Figure 4, dying of nodes and increase trend of them in different rounds are outlined in both two scenarios.

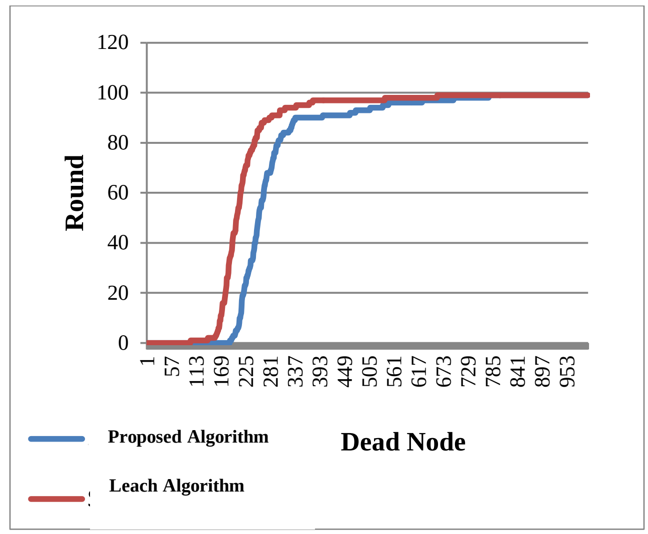

Figure 4 : Dead Node in Each Round

As indicated in Figure 5, in each round on average 55 to 60 percent of images remove and only 35 to 40 percent of images send.

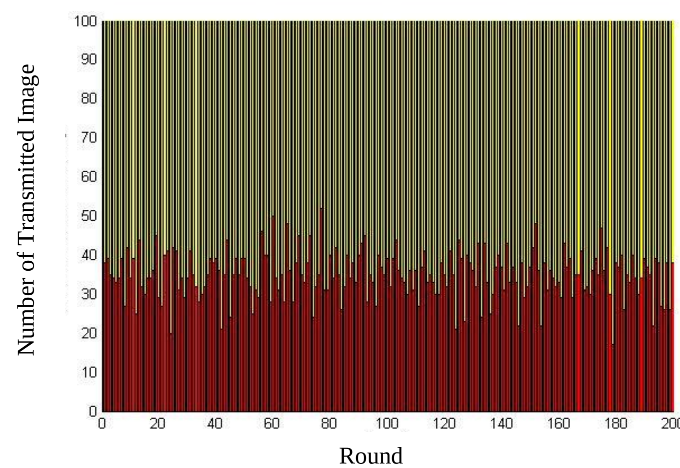

Figure 5 : Comparison of Number of Transmitted Image in Each Round

6- CONCLUSIONS

Due to the importance of increase lifetime and decrease energy consumption in sensor network, in this paper a method is proposed in order to aggregate data in cluster head. This method uses SVD to avoid sending similar images. Network longevity is compared to LEACH through this algorithm, and the simulation results show the use of this algorithm for aggregating data increase network lifetime about 50 percent.

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