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Energy Efficient Transmission in Wireless Sensor Networks using Compressed Sensing Technique

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Abstract:- Minimizing the energy consumption and prolonging the network lifetime through efficient data transmission are open research problems in practical Wireless Sensor Networks (WSNs). The proposed work focuses on data transmission based on Compressive Sensing (CS). Compressive sensing refers to the signal processing technique of sampling a sparse signal at sub-Nyquist frequencies, and to recover the same by finding solutions to under-determined linear system of equations. The performance of this method on Low Energy Adaptive Clustering Hierarchy (LEACH) is investigated in this work. Simulation results show that Compressive Sensing based method outperforms in terms of energy efficiency as well as network lifetime.

I. INTRODUCTION

Wireless sensor networks (WSNs) contribute to the rapid advancement in the Internet of Things (IoT) throughout the world. WSNs consist of a large number of sensors deployed over an area to monitor environments, track objects, control various industrial operations etc. The development in technology has led to an increasing interaction between information processing and the physical world due to which the deployment and the very same concept of sensing is changing rapidly. Sensors are used to measure the parameters such as temperature, pressures, pollution and so on in their vicinity. Then, these sensors transform the measurements obtained into signals that carry the information of the sensed physical parameters occurring in the environment surrounding them. So, the basic operation of sensor nodes is to sense, process and communicate the data to the required destination.

The sensor nodes operate in low power mode such that recharging or replacing them may not be possible especially in remote areas. So, the main design issue in WSN is to reduce the energy consumption in the network and thereby prolong the network lifetime. A main portion of the energy consumption takes place during processing and transmission of the sensed data. The data sensed by these nodes has to finally reach the Base Station (BS). If each sensor node directly transmit these data to the BS, a large amount of energy will be consumed in this process. Thus, different energy efficient clustering and routing protocols were developed such as Low Energy Adaptive Clustering Hierarchy (LEACH) [1], Stable Election Protocol (SEP) [2], Threshold sensitive Energy Efficient sensor Network (TEEN) [3] etc. where the region to be sensed was divided into a number of clusters. Each cluster consist of a Cluster Head (CH). All the cluster members send the data to the BS via their respective CHs, which reduced the number of long distance transmissions involved while sending data to the BS.

Another method of reducing energy consumption is to allow only a few selected sensor nodes to transmit the sensed data to the BS. This method is an implementation of Compressive Sensing (CS) [4], [5] applied to the WSNs. Instead of transmitting the data from all the sensor nodes and later compressing them, this method focused on compressing the data at the time of sensing itself. This could further reduce the quantum of data to be transmitted and thus reducing the energy consumption.

The major challenge faced in the design of the WSN is that the sensor devices are battery-limited in terms of energy capacity. Once the batteries of the sensor nodes are drained out, replacing them may be infeasible. In some applications of WSNs such as detection of volcanic and seismic activities, the replacement of batteries may be practically impossible. So, the main objective is to prolong the network lifetime by reducing energy consumption in the WSNs. To achieve this aim, a combination of different clustering and routing protocols such as LEACH, SEP and TEEN along with PCI-CS has been used. CS technique leverages the sparsity prior to reduce the amount of scalars that represent a signal [6, 7].

II. LITERATURE REVIEW

A major portion of the energy consumption of sensor nodes is contributed by data communication. So, the amount of data transmission in the WSN is to be minimized in order to minimize energy consumption in the network. CS [4,8,9] is an emerging technology which serves this purpose. In CS, data from the sensor nodes are picked up and a linear combination of them are transmitted. This may increase the computational complexity, had CS been applied to all the nodes. To deal with this, hybrid CS [5] has been developed where CS is applied to only the CHs. In hybrid CS, all sensor nodes other than the CHs transmit data without using CS and only CHs transmit data to the base station via CS. CS based data gathering was proposed on routing trees before it was proposed on cluster-based routing.

For applying CS in WSNs, the signal has to be sparse. Sparsity of the signal ensures that its reconstruction is possible at the receiver from the linear combination of its input samples [10,11,12]. The sensing or measurement matrix used in CS is usually taken as a Gaussian matrix. Partial Canonical Identity matrix [13], when used as the sensing matrix could perfectly reconstruct the signal received at the BS and was proposed in [6].

Several optimal node deployment strategies [19,20] exist through which the sensor nodes can be distributed in a geographical area. However, random deployment of sensor nodes are preferred here. The data from all the sensor nodes has to finally reach the BS. IF the network is of higher size, its coverage also will be larger and the direct transmission of data to the BS may become infeasible. If all the sensors are directly sending their data to the BS, this would consume more energy as the far away nodes from the BS has to transmit data to a longer distance. Thus, the cluster-based routing was proposed [1,2,3,5]. LEACH was such a clustering protocol proposed. CH rotation was then proposed to ensure that the CHs do not drain out their energy faster and become dead. Adjusting the sensing radius [21,22] of some of the sensor nodes could also prolong the network lifetime as only some of the sensor nodes would be active throughout and the other nodes would turn on only when some activity is detected. Protocols such as SEP were developed which used the concept of advanced nodes which has much more energy compared to normal nodes. TEEN protocol is another cluster-based protocol used to transmit only the data that falls within a specified range.

III. CLUSTERING AND ROUTING PROTOCOLS

Energy efficiency is an important point which should be taken care at time of design of wireless sensor network. Energy-efficient routing protocols has been developed to minimize the energy spend since WSNs work on limited power and the energy discharge is proportional to the quantum of transmission. Here, different types of energy efficient clustering and routing protocols has been used such as LEACH, SEP and TEEN.

3.1 Low Energy Adaptive Clustering Hierarchy Protocol

LEACH [1] is a form of clustering technique that comprise of self organisation of the sensor nodes deployed and allows CH rotation for even distribution of the energy. The nodes are organised into clusters, with one CH node for every cluster. The non-CH cluster members transmit their data toward the CH. The CH nodes collects data from the corresponding members of its cluster members and then transmits the collected data to the BS located far apart. Thus, the energy spend of a CH node is significantly higher than that of a non-CH node.

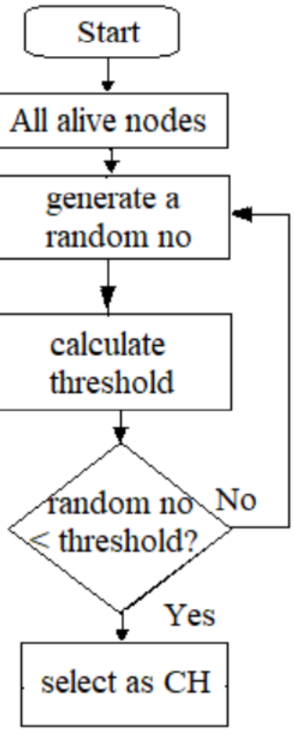

Fig. 1. Flowchart of LEACH protocol

The LEACH protocol works as described in Figure 1. The operation of LEACH protocol is in two phases namely the set-up phase and the steady state phase. In the first phase, the clusters are organised and in second phase, the data from the sensor nodes are transferred to the BS via their corresponding CHs. The set-up phase begins with the CH selection process.

IV. COMPRESSIVE SENSING

A common goal of the engineering field of signal processing is to reconstruct a signal from a series of sampling measurements. In general, this task is impossible because there is no way to reconstruct a signal during the times that the signal is not measured. Nevertheless, with prior knowledge or assumptions about the signal, it turns out to be possible to perfectly reconstruct a signal from a series of measurements (acquiring this series of measurements is called sampling). Over time, engineers have improved their understanding of which assumptions are practical and how they can be generalized. Compressed sensing [14, 15](also known as compressive sensing, compressive sampling, or sparse sampling) is a signal processing technique for efficiently acquiring and reconstructing a signal, by finding solutions to under-determined linear systems. This is based on the principle that, through optimization, the sparsity of a signal can be exploited to recover it from far fewer samples than required by the Nyquist–Shannon sampling theorem[16]. There are two conditions under which recovery is possible. The first one is sparsity, which requires the signal to be sparse in some domain. The second one is incoherence, which is applied through the isometric property, which is sufficient for sparse signals[17,18]

V. PROPOSED METHOD

This chapter discusses about the methodology used in the project. A detailed discussion on the proposed method, the work done and the experimental set up is given below. The WSN consists of large number of sensors randomly deployed in a geographical area. Initially, some of these nodes are randomly selected which acts as CHs. The non-CHs will join the nearest CH and thus become a member of that particular cluster. Thus, clusters are formed which includes a CH and its respective cluster members. Once each node select its CH, the sensed data is transmitted by the node to the BS via their respective CHs. These processes namely, CH selection, choosing the cluster members, cluster formation and thus deciding the path through which data has to reach the BS are implemented using different energy efficient clustering and routing protocols.

VI. RESULTS AND DISCUSSION

The major problem faced while developing a WSN is that it is a hectic task to replace the sensors if their batteries are drained out. Various energy efficient clustering and routing protocols such as LEACH, SEP, TEEN etc. already exist which has been successful in improving energy efficiency thereby prolonging the network lifetime. Out of these three protocols, TEEN protocol has been found to show better performance. In addition to these energy efficient clustering and routing protocols, energy efficient data gathering methods such as CS and PCI-CS has been implemented which has shown a tremendous increase in energy efficiency as well as network lifetime. Figure 2 shows the plot of average energy vs packets sent to base station while using LEACH protocol.

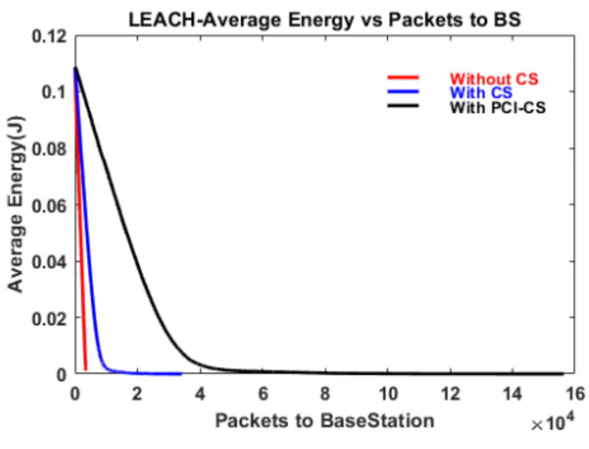

Fig. 3. Average Energy of nodes vs Packets to BS using LEACH protocol

VII. CONCLUSION

The main objective of the sensor network is to collect the data generated in the deployed field and to transmit it to the BS. The process of data transmission and reception especially over long distances is really energy consuming. In most of the cases, once the sensor batteries are drained out, it is practically impossible to replace them. In order to achieve this aim of minimizing the energy spend and thereby prolonging the network life-time, several clustering and routing protocols such as LEACH.

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