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A Novel Energy Balanced Backbone Construction for Dense WSNs

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Abstract— Wireless Sensor Network (WSN) consists of battery operated sensor devices that are deployed in random fashion to accomplish a specific task. To analyze dense wireless sensor network, we propose a methodology that utilizes spanning tree protocol, graph sampling and connected dominating sets in sequence. Spanning tree protocol improves the connectivity of the graph, graph sampling reduces complexity of the network and the connecting dominating sets is used to construct a backbone. The backbone framework obtained is much energy efficient as compared to the existing model. Our results prove that our methodology has reduced the energy consumption of the backbone framework by 27%.

Keywords— Wireless Sensor Network; Spanning Tree Protocol; Connecting Dominating Set; Graph Sampling; Dominating Nodes; Backbone framework

I. INTRODUCTION

Today wireless sensor networks has the potential to remodel many sections of our economic and social life, starting from environment conservation and monitoring, to industrial management and also in transportation and heath care field. The complete working of such a sensor network depends upon the implementation of protocols, signal processing, algorithms and data management unanimously. The working of these networks depend on constrained battery operated sensor devices. The advancement in the arena of wireless networking has led to the development of hefty sensor networks that meet the needs of many military and commercial applications. The sensor networks help in analysing physical environment. The data that is gathered by or transferred on a sensor network describes the surroundings of the environment like humidity, temperature etc. The sensor nodes after sensing the changes in the physical surroundings, reports them to the other nodes in the network. In dense WSNs, proper functioning of the sensor nodes is vital to accomplish a particular task. The sensor nodes can function for a longer duration only when the energy of the network is effectively and efficiently utilized.

When the sensor nodes are deployed in a close fashion, it leads to development of dense WSNs. The sensor nodes are designed to accomplish a particular task which a single node cannot achieve. Hence, these sensor nodes in collaboration with other nodes are used to achieve the assigned task. The WSN provide its applications in the field of specie mapping, forest fire detection etc. The dense WSNs are difficult to analyse as they consist of a large number of sensor node. Hence, a backbone is generally constructed for effective delivery of data. The backbone developed forms the centralized framework of the topology resulting in efficient data delivery. The major difficulties that have to be faced during the construction of the backbone is the looping problem. The transferred packet might enter in the state of infinite looping due to lack of or incomplete routing information with nodes. Hence, to prevent a packet from entering in this state, a backbone is constructed for the effective delivery of the data. The dominating nodes or the backbone nodes are used to carry out the routing process. Hence, backbone construction helps in efficient data delivery.

The rest of the paper is described as: Section II represents the motivation; Section III explains the experimental design; Section IV draws the inferences and Section V gives the conclusion and future work.

II. MOTIVATION

According to the simulations shown in [1], the introduction of the concept of the algebraic connectivity has helped in building an energy efficient backbone In order to improve the efficiency in the construction of backbone in terms of stability, robust nature, effective routing and capacity, algebraic connectivity is evaluated on the basis of cost and number of connections in the network. Most of the researchers have focused on the construction of the backbone with minimum number of nodes for a give WSN network. In [2], the authors have focused on the construction of the backbone, considering the properties of the network nodes in diversified ad-hoc networks. The nodes properties may differ in terms of capacity, energy consumption and computational power.

In [3], the authors have constructed a centralized backbone framework in a dense WSN network using graph sampling and Connecting Dominating Set (CDS) technology. Graph sampling techniques are used to reduce the size of the network and connecting dominating set approach is implemented to build a backbone framework. A selective approach is implemented for the construction of backbone in [4] by selecting a limited number of kernel nodes and then the topological report is diffused outwards from the kernel nodes to make appropriate selection decision making. In [5], a discrete approach is proposed to construct an implicit backbone. This implicit backbone allows the exchange of limited control messages that would help in effective data transmission in cognitive radio. In [6], MCMICS approach is used for the construction of backbone to achieve three objectives; minimal backbone length, swift development and resistant nature which has led to decreased overhead during communication. In [7], the authors have devised an algorithm that considers the size and the length of the path that the packet has to travel for building of the backbone.

Backbone with fault tolerant capability is also constructed by the authors of [8]. The backbone is developed with sleep and awake agenda which helps in faster recovery from the faults and also increases the accuracy of the system. The concept of the construction of virtual backbone has also helped in the minimizing the cost that is required to transfer the data from one node to another [9]. In [10], a new algorithm is proposed in which the backbone is maintained even if some of the backbone nodes opt to get into sleep status.

In [11], an enhanced version of MAC protocol is used to optimize wireless sensor networks in terms of performance and fairness. A link adaptation technique is used to improve the utilization of energy in an efficient way. In [12], a scheduling scheme is used to enhance energy efficiency. This scheduling algorithm is based on a two-tier architecture. Using this scheme the sensor nodes are allowed to enter into sleep mode. The sensor nodes may be put into either of the two sleep modes: continuous sleep and periodic sleep. This helps in restraining the nodes from entering into idle state hence, improving energy efficiency.

In [13], the power consumed by the WSN network to transfer data is taken under consideration. After analysing the power consumed for data transmission, a sensor with the same power configuration is used along with the time scheduling technique for receiving data. The results show that this technique has helped in increasing the lifetime of a sensor node by 32%. In [14], a novel framework is developed by combining energy harvesting routing technique with duty cycling for conserving the bandwidth and the energy of the WSN network. It is inferred that the energy conservation is improved from 13% to 50%.

III. EXPERIMENTAL DESIGN

The wireless sensor networks change their behavior according to the node density in the various deployments. The higher the density of the sensor networks, higher is the amount of energy consumed, leading to lower lifetime. The sensor networks consists of battery operated devices, which require several energy efficient techniques to be deployed with the sensor networks for increasing the network lifetime. Efficient routing and backbone construction became the primary tasks for such WSNs. The major issue relates with the efficient backbone construction, which acts as the primary data handling network of the dense WSN. The dominating nodes inherit several properties such as higher order of connectivity, elongated battery life, sometime higher configuration nodes, etc.

In this research, the primary focus is to efficiently connect the nodes of dense WSNs, using efficient mechanisms such spanning tree protocol (STP) and connected dominating sets (CDS). The graph sampling technique have been used to shortlist the higher order nodes to form the backbone connectivity. The graph sampling is responsible to filter the lower degree/order nodes (weakly connected, less configuration or lower lifetime sensor nodes) from the network, leading to the development of energy balanced backbone framework. The methodology followed in the construction of energy balanced backbone is explained as under:

1. Spanning Tree Protocol:

Spanning tree algorithm [15] is implemented on a given dense WSN network. The implementation of the protocol is done to obtain a tree structure, free of loops and redundant links. The lower order nodes are tightly connecting to higher order nodes leading to increased connectivity.

2. Graph Sampling:

This technique is done to reduce the complexity of the network. For dense WSN, the implementation of graph sampling plays a vital role. There are many graph sampling algorithms [16] that are being deployed to reduce the connectivity of the network.

3. Connecting Dominating Sets (CDS):

CDS technique [17] is used to obtain the backbone framework of the network. The backbone obtained is the centralized framework that is used to perform all the routing functions. The development of backbone leads to efficient delivery of data.

IV. SIMULATION RESULTS

The simulation tool used to implement the above methodology is MATLAB. The number of nodes that constitute a WSN network is 200. The transmission radius (Tr) is kept as 50 meters, as for efficient communication the backbone nodes should be in the range of each other. The original network of 200 nodes is shown in Fig 1. The spanning tree along with CDS is implemented on the original network. Then graph sampling algorithm is deployed to reduce the complexity of the network. The network obtained as a result of graph sampling technique is shown in Fig 2. The sampled graph consists of 100 nodes.

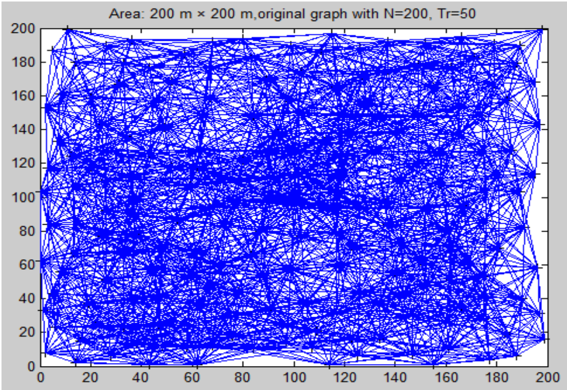

Fig 1. Original Graph with 200 nodes, Tr=50

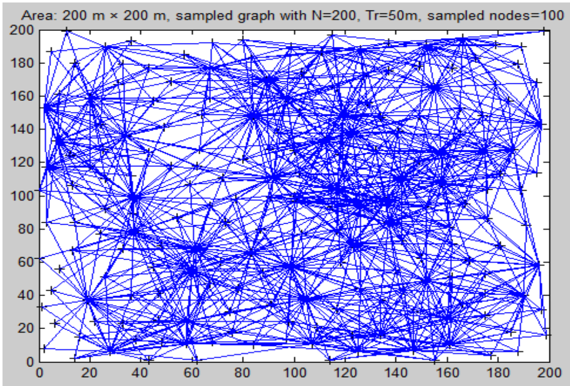

Fig 2. Sampled Graph with 100 nodes, Tr=50

The CDS technique is implemented on the sampled graph to obtain the backbone structure. The backbone framework obtained for both original and sampled graph is shown in Fig 3. and Fig 4. The number of backbone nodes obtained by above methodology in original graph is 13 and sampled graph is 10 which is less as compared to the results obtained in [3].

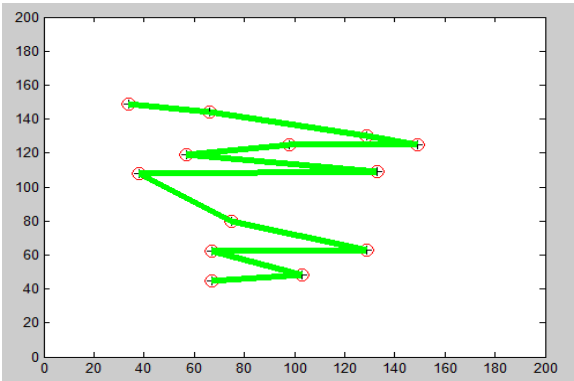

Fig 3. Backbone Framework for Original Graph

The backbone nodes are selected on the basis of energy and degree of the nodes. Both the parameters are integrated to obtain a cost function. The higher the cost function, the higher is the probability for a node for getting selected as a backbone node. The resultant framework obtained considering the two factors are said to be energy efficient.

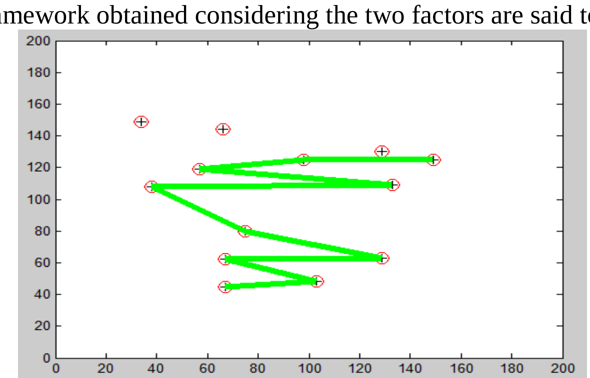

Fig 4. Backbone Framework for Sampled Graph

Graph sampling should be done in such a way that the properties of the original graph are similar to that of the sampled graph. This similarity is achieved by taking the energy and connectivity levels of the backbone framework in consideration. The similarity of the original and the sampled graph is shown in Fig 5 and Fig 6. We infer from Fig 5 and Fig 6 that sampling is done in an efficient way as the pattern obtained are similar.

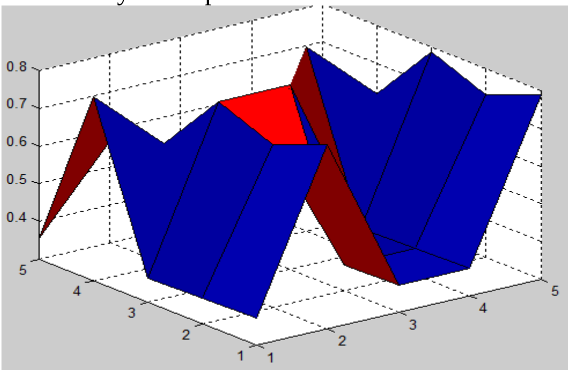

Fig 5. Pattern for Original Graph

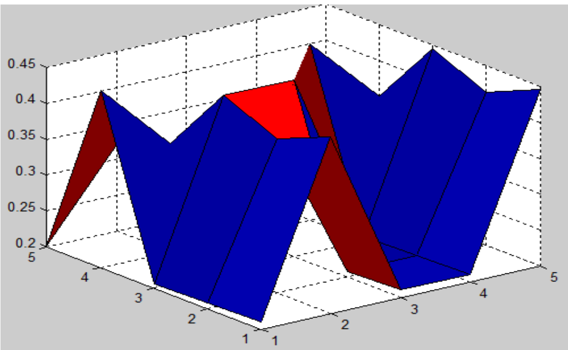

Fig 6. Pattern for Sample Graph

The plot of the number of backbone nodes to transmission radius is shown in Fig 7 which is less as compared to the result in [3].

The energy consumption of the backbone framework is calculated and it is inferred that our methodology consumes 27 % less energy as compared to the existing model in [5].

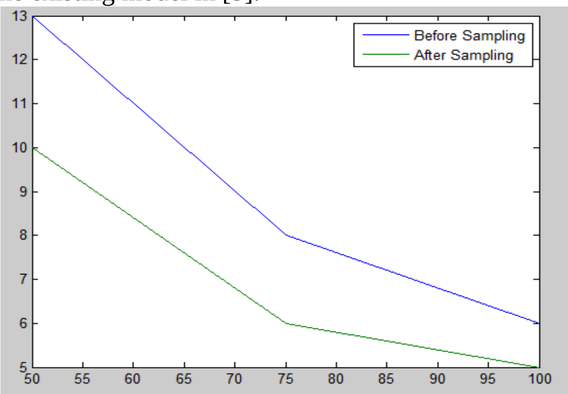

Fig 7. Plot of bakbone nodes v/s transmission radius

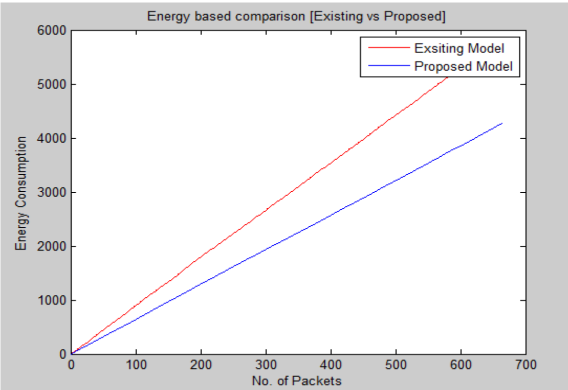

Fig 8. Energy Consumption of Existing Model and Proposed Model

V. CONCLUSION AND FUTURE SCOPE

WSNs consists battery operated sensor devices that are deployed for various applications. Analysis of dense WSN is difficult. The proposed methodology utilizes a spanning tree protocol, graph sampling and connecting dominating set that will help in the construction of an energy efficient backbone framework. The existing model utilized graph sampling and connecting dominating sets to construct a backbone but the limitation of the existing model was that it did not take into consideration the non-dominating nodes.

The proposed methodology at an earlier step implements spanning tree protocol that provides better connectivity to the network by tightly connecting the dominating nodes and the non-dominating nodes. Then graph sampling and CDS technology is implemented to reduce the complexity of the network and also to generate a backbone framework. The proposed methodology is simulated using MATLAB and the results show that our methodology has reduced the energy consumption of the backbone framework by 27% as compared to existing model.

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