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An energy efficient network life time enhancement proposed clustering algorithm for Wireless Sensor Networks

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ABSTRACT: wireless sensor networking is an emerging technology that promises a wide range of potential applications in both civilian and military areas. A wireless sensor network (WSN) typically consist of a large number of low cost, low power and multi-functional sensor nodes that are deployed in a region of interest. Wireless sensor networks face many challenges caused by communication failures, storage and computational constraints and limited power supply. In WSN, the nodes are battery driven and hence energy saving of sensor nodes is a major design issue. Energy efficient algorithms must be implemented so that network lifetime should be prolonged. Lifetime of a network can be maximized through clustering algorithms, where cluster is responsible for sending the data to the base station and not all the nodes are involved in data transmission .various clustering algorithms are deployed in past few years. In this paper we are proposing an algorithm which is a combination of Bacterial foraging optimization algorithm (BFO) which is a Bio-Inspired algorithm and LEACH and HEED protocols which enhances the lifetime of a network by dissipating minimum amount of energy.

Keywords: WSN, Bacterial Foraging Optimization, LEACH, HEED.

1. INTRODUCTION

Wireless sensor networks [3] are an emerging technology that has potential applications in surveillance, environment and habitat monitoring, structural monitoring healthcare and disaster management. A WSN monitors an environment by sensing its physical properties. It is a network of tiny, autonomous nodes that can acquire process and transmit sensory data over wireless medium. Typically, sensor nodes are grouped in clusters and each cluster has a cluster head. All the nodes forward their sensor data to the cluster head, which in turn routes it to a specialized node called sink node (Base Station) through a multi-hop wireless communication as shown in the figure. However often the sensor network is very small and consists of a single cluster with a single base station. Other scenarios such as multiple base stations or mobile nodes are also possible.

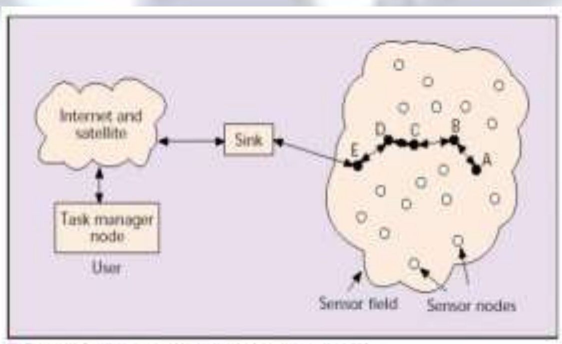

Figure 1. *Sensor nodes scattered in a sensor field.*

WSN issues such as node deployment, localization, energy aware clustering and data aggregation are often formulated as optimization problems. Traditional analytical optimization techniques such as linear, non-linear and quadratic programming, Newton-based techniques and interior-point methods require enormous computational efforts, which grow exponentially as the size of the problem increases. An optimization method that requires moderate memory and computational resources and yet produces good results is desirable, especially for implementation on an individual sensor node. These give motivation for heuristic algorithms such as PSO [10], [5], Genetic algorithm (GE) [6], differential evolution (DE) [7] and Bacterial Foraging Algorithm (BFO) [1]. Bio-Inspired optimization methods are computationally efficient to analytical methods.

2. ARCHITECTURE OF WIRELESS SENSOR NETWORK

Architecture of the wireless sensor network [11] consists of the following components.

(a). **sensor node**: a sensor node is the core component of the wireless sensor network because it can perform multiple roles In a network, such as sensing, data processing, data storage and routing.
(b). **Clusters:** Clusters are the organization unit for WSNs. The dense nature of these networks requires the need for them to be broken down into clusters to simplify tasks such a communication.
(c). **Cluster Heads:** cluster heads are the organization leader of a cluster. They often are required to organize activities in the cluster. These tasks include but are not limited to data-aggregation and organizing the communication schedule of a cluster.
(d). **Base Station:** the base station is at the upper level of hierarchical WSN. It provides the communication link between the sensor network and the end user.
(e). **End-User:** The data in the sensor network can be used for a wide range of applications [3] .Therefore for a particular application may make use of the network data over the internet, using a PDA, or even a desktop computer. All the processing is done at the end user when data from various nodes are collected.

3. BACKGROUND STUDY

3.1 Low-Energy Adaptive Clustering Hierarchy (LEACH)

LEACH [2] protocol that is proposed by Heinzelman et al is an elegant solution to power constraint problem, by forming enough number of clusters in a self organized manner. It is the first dynamic cluster head protocol specifically for WSN using homogenous stationary sensor nodes randomly deployed. LEACH is suited for applications which involve constant monitoring and periodic data reporting. LEACH protocol runs in many rounds. Each round contains two phases: cluster setup phase and steady phase.
In cluster setup phase, it performs organization of cluster and selection of cluster head. Selected cluster heads broadcast a message to all the other sensors in the network informing that they are the new cluster heads. All non cluster head nodes which receive this advertisement decide which cluster they belong to based on the signal strength of the message received. All non cluster head nodes transmit their data to the cluster head, while the cluster head transmit the data to the remote station that is the base station (BS). Cluster head node is much more energy sensitive than being a non-cluster node. Head nodes would quickly use up their limited energy. Thus, LEACH incorporates randomized rotation of the high-energy cluster head among the sensors.
The sensor nodes elect themselves to be cluster head at any given time with a given probability. The decision of whether a node elevates to cluster head is made dynamically at a time interval. The elevation decision is to be made solely by each node independent of other nodes. This is done to minimize overhead in cluster head establishment. This decision making is a function of the percentage of optimal cluster heads in a network (to be determined prior to application) in combination with how often and the last time a given node has been a cluster head in the past. The threshold function is defined as:
T (n) = {P/ (1-P (rmod (1/P)) if n€G
0 otherwise}
Where **n** is the given node, **P** is the a priori probability of a node being elected as a cluster head, **r** is the current round number and **G** is the set of nodes that have not been elected as cluster heads in the last **1/P** rounds. Each node during Cluster head selection will generate a random number between 0 and 1. If the number is less than the threshold **(T (n))** the node will become a cluster head.

3.2 Hybrid Energy-Efficient Distributed Clustering (HEED)

Hybrid Energy-Efficient Distributed Clustering (or HEED) [4] is a multi-hop clustering algorithm for wireless sensor networks, with a focus on efficient clustering by proper selection of cluster heads based on the **physical distance** between nodes. The main characteristics of HEED algorithm are to:

(a). Distribute energy consumption to prolong network lifetime;
(b). Minimize energy during the cluster head selection phase;
(c). Minimize the control overhead of the network.

The most important aspect of HEED is the method of cluster head selection. The selection of cluster head is basically depends upon the following two parameters:
1) **The residual energy** of each node is used to probabilistically choose the initial set of cluster heads. This parameter is very commonly used in many other clustering schemes also.

2) **Intra-Cluster Communication Cost** is used by nodes to determine which cluster they are going to join. This scenario is useful if a given node falls within the range of more than one cluster head. In HEED it is important to identify the range of a node is in terms of its power levels as a given node will have multiple discrete transmission power levels. The power level used by a node for intra-cluster announcements and during clustering is referred to as cluster power level. Low cluster power levels promote an increase in spatial reuse while high cluster power levels are required for inter-cluster communication as they span two or more cluster areas. Therefore, when choosing a cluster, a node will communicate with the cluster head that yields the lowest intra-cluster communication cost. The intra-cluster communication cost is measured using the Average Minimum Reach-ability Power (AMRP) measurement. The AMRP is the average of all minimum power levels required for each node within a cluster range **R** to communicate effectively with the ith cluster head. The AMRP of ith node then become a measure of the expected intra-cluster communication energy if this node is elevated to cluster head. Utilizing AMRP as a second parameter in cluster head selection is more efficient then a node selecting the nearest cluster head.

3.3 BIO-INSPIRED ALGORITHM [9]

3.3.1 Bacterial foraging algorithm (BFO)

Bacterial Foraging [8] Optimization Algorithm (BFO) [1] is a well-known computational methodology which is based on the study of the bacterial foraging behaviors. The complex but organized activities exhibited in bacterial foraging patterns could inspire a new solution for optimization problems. The underlying mechanism of the surviving of bacteria, especially E. coli in a complex environment has been reported by researchers in the area of biological sciences. Inspired from these phenomena, BFO was developed as an optimization algorithm by K. M. Passino [1], in which the self-adaptability of individuals in the group searching activities has attracted a great deal of interests. The classical bacterial foraging optimization (BFO) system consists of three principal mechanisms, namely, chemo taxis, reproduction, and elimination dispersal.

Chemotaxis: This process simulates the movement of an E.Coli cell through swimming and tumbling via flagella. Biologically an E.Coli bacterium can move in two different ways. It can swim for a period of time in the same direction or it may tumble, and alternate between these two modes of operation for the entire lifetime.
Swarming: An interesting group behavior has been observed for several motile species of bacteria including E.coli and S. typhimurium, where intricate and stable spatio-temporal patterns (swarms) are formed in semisolid nutrient medium. A group of E.coli cells arrange themselves in a traveling ring by moving up the nutrient gradient when placed amidst a semisolid matrix with a single nutrient chemo-effecter. The cells when stimulated by a high level of succinate, release an attractant aspertate, which helps them to aggregate into groups and thus move as concentric patterns of swarms with high bacterial density.
Reproduction: The least healthy bacteria eventually die while each of the healthier bacteria (those yielding lower value of the objective function) asexually split into two bacteria, which are then placed in the same location. This keeps the swarm size constant.
Elimination and Dispersal: Gradual or sudden changes in the local environment where a bacterium population lives may occur due to various reasons e.g. a significant local rise of temperature may kill a group of bacteria that are currently in a region with a high concentration of nutrient gradients. Events can take place in such a fashion that all the bacteria in a region are killed or a group is dispersed into a new location. To simulate this phenomenon in BFOA some bacteria are liquidated at random with a very small probability while the new replacements are randomly initialized over the search space.

4. PROPOSED ALGORITHM

All the clustering algorithms that we have studies here have their own pros and cons. In our proposed algorithm we primarily focus on increasing the life-time of the network so that energy nodes will not die soon and the life time of network should be prolonged. The proposed algorithm is implemented in 3 phases:

(a). **phase 1:** the nodes will be moved within the cluster through the foraging strategy of the E.Coli bacteria that is proposed in bacterial foraging optimization (BFO) [1]. The sensor nodes are moved within in the cluster so that a proper inter-node distance (calculated prior to the application) is maintained. This distance is enforced into the algorithm because if the nodes move so close then it may happen after n iterations that they accumulate in the same region. It should be avoided because if they are accumulated in the small area then the data they sense will be duplicated and that is not desirable in the network. Hence a proper inter node distance is maintained. Also, it may happen that some nodes are moved so far away from the other nodes in the cluster then they will took more energy from the battery and will die soon. This is also not a favorable situation because we know that wireless sensor nodes are battery driven and it is not possible in most cases to replace the battery, as our aim in this algorithm is to prolong the network lifetime.

(b). Phase 2: In the second phase of the algorithm we select the cluster head according to the LEACH [2] protocol and the HEED [4] protocol. This will work as; the selection of the cluster head is according to the probability function given in the LEACH protocol and the residual energy of the sensor node. The more is the residual energy the more are the chances of a sensor node to become a cluster head. It is because of the fact that as we know that cluster head communicates directly with the base station so cluster head will require more energy. Hence the senor nodes that have the highest residual energy have the highest probability of being selected as cluster head.

(c). Phase 3: In the third phase of the algorithm, the actual transmission of the data is done. In this phase the cluster heads gather the data sensed by the sensor nodes in their cluster region and then it will send the data to the base station. The transmission can be either by a multi-hop method or can be single hop. In multi-hop method, the cluster head can send data to another cluster head and it can then send to the base station. This scenario is followed because sometimes some cluster head are far away from the base station and if they directly send the data to the base station they will deplete their energy very soon. Hence it can be avoided by multi-hop method. In single hop method, cluster heads are directly send the data to the base station. This scenario is helpful in those cases where the network is very small.

5. LIMITATION OF THE WORK

The proposed algorithm is just a proposed algorithm and the algorithm is justified only when the simulation will be carried out by using a proper simulator. Hence the work is purely an idea for the clustering in the wireless sensor networks so that network life time should be increased.

6. CONCLUSIONS AND FUTURE WORK

Scalability and density of deployments, environmental uncertainties and constraints in energy, memory, bandwidth and computing resources pose serious challenges to the developers of WSNs. Issues of node deployment; localization, energy-aware clustering and data aggregation are often formulated as optimization problems. Many analytical methods suffer from slow or lack of convergence to the final solutions. The bio-inspired algorithms are inspired from the nature's perfection to deal with complex scenarios. So the wireless networks developers are learning from the nature how it's dealing with problems from ages. . In this paper we have proposed an energy efficient algorithm which enhances the lifetime of the wireless sensor network.

Future work can be done by simulating the above stated algorithm by using simulators by setting up the parameters to check whether the algorithm is enhancing the lifetime of the network or not. The performance analysis of the algorithm must be performed by doing the simulations.

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