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Modification in Leach algorithm for Energy Efficiency in Wireless Sensor Networks: A Survey

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***Abstract*—** This paper summarizes the work used to improve low energy adaptive cluster hierarchy (LEACH) algorithm. Several methods have been used to increase the lifetime and decrease the pace of disintegration or early death of nodes in wireless sensor networks. Several traditional methods (Grid based or multi hierarchical methods) and metaheuristic techniques such as particle swarm optimization and simulated annealing methods have been used for even energy and spatial distribution of clusters in LEACH.

Keywords- LEACH, WSN, Clustering

I. INTRODUCTION

There exists a considerable research effort for the development of routing protocols in WSNs. The development of these protocols is based on the particular application needs and the architecture of the network. However, there are several factors that should be taken into consideration when developing routing protocols for WSNs. Energy efficiency is the most important among these factors, since it directly affects the lifetime of the network. There have been a few efforts in the literature pursuing energy efficiency in WSNs.

Heinzelman et.al [1] introduced Low Energy Adaptive Clustering Hierarchy (LEACH), a hierarchical protocol in which most nodes transmit to cluster heads, is presented. The operation of LEACH consists of two phases: the setup phase & the steady state phase. In the setup phase, the clusters are organized and the cluster heads are selected. In every round, a stochastic algorithm is used by each node to determine whether it can become a cluster head. If a node becomes a cluster head once, it cannot become a cluster head again for *P* rounds, where *P* is the desired percentage of cluster heads. In the steady state phase, the data is sent to the base station. The duration of the steady state phase is longer than the duration of the setup phase in order to minimize overhead.

LEACH is a protocol that tends to reduce energy consumption in a WSN. However, LEACH uses single-hop routing in which each sensor node transmits information directly to the cluster-head or the sink. Therefore, it is not recommended for networks that are deployed in large regions. But it has various shortcomings. In LEACH, cluster heads send aggregated data to base station in single hop manner so consumes lot of energy. Cluster heads are predefined typically taken as 5% or 10% of total deployed nodes. Probability function doesn't take residual energy of node while selecting cluster heads. It consists of rounds, while in each round, all sensor nodes take part in reconstructing new clusters and this consumes a lot of energy. Cluster size changes significantly as cluster heads are selected on random basis so the deployed nodes drain out their power unevenly which affects network connectivity, consequently lifetime of network. Clusters strength is imbalanced.

II. LEACH IMPROVEMENTS IN LITERATURE

Since LEACH has many drawbacks, various improvements have been done to use the node energy effectively, minimize the energy consumption of node and maximize the network lifetime in recent years. Yuh-Ren Tsai [31] proposed a coverage-preserving routing protocol for randomly distributed WSNs, modified from the LEACH and the virtual grid routing protocols. Different nodes are assigned different probabilities of being a cluster-head, relating to the normalized effective sensing area of this node, in order to maximize the network sensing coverage. Simulation results found that the proposed protocols outperform other baseline protocols in network sensing coverage with a gain of 20% in the middle phase. If the network sensing coverage threshold for a normal functioning network is $C \geq 50\%$, the life-time of a network can be extended by 150 to 250 rounds by using the proposed protocols. Abdul Latiff *et. al.* [14] presented a particle swarm optimization (PSO) based energy-aware cluster protocol for WSN. In this a new cost function has been defined which takes into account the maximum distance between the non-cluster head node and its cluster head, and the remaining energy of cluster head candidates in the cluster head selection algorithm. Results from the simulations indicate that the proposed protocol using PSO algorithm gives a higher network lifetime and delivers more data to the base station compared to LEACH and LEACH-C. Furthermore, the proposed protocol produces better clustering by evenly allocating the cluster heads throughout the sensor network area. M. Bani Yassein *et. al.* [36] presented a new version of LEACH protocol called V-LEACH protocol by proposing a backup for each cluster head. In this way the number of messages created by the V-LEACH is less than the messages created by the original LEACH and thus energy requirement can be decreased.

Ran and others [24] presented a method based on the improvement of LEACH by using fuzzy logic based cluster heads selection by choosing battery level, distance and node density as factors. Ben Alla *et. al.* [25] presented IB-

LEACH which improves the stable region of the clustering hierarchy and decrease probability of failure nodes using the characteristic parameters of heterogeneity in networks. In these networks some high energy nodes called NCG nodes (Normal node or Cluster Head or Gateway) become "cluster heads" to aggregate the data of their cluster members and transmit it to the chosen "Gateways" that requires the minimum communication energy to reduce the energy consumption of cluster head and decrease probability of failure and this increase the lifetime of the network.

Simulation results show better performance. Chakraborty *et. al.* [5] presented an energy efficient data gathering scheme using particle swarm optimization (PSO) with Simulated Annealing (SA) to form a sub-optimal data gathering chain and devised a method for selecting an efficient leader for communicating to the base station. This helps to rule out the unequal energy dissipation by the individual nodes of the network and results in superior performance as compared to LEACH and PEGASIS. Xiaoping *et. al.* [35] presented an improved routing algorithm based on leach protocol an which involves cluster head choosing, multi-hop routing and the building of its path. Simulation in MATLAB, an improved routing algorithm has higher energy utilizing rate, and it helps prolong network's lifetime.

Omranpour *et. al.* [22] presented an evolutionary algorithm to find optimum cluster heads and the best clustering in WSN. The new method performs better in comparison with Simulate Annealing. This is achieved by proper definition of selection, mutation and crossover operators, and also the type of survival selection. Katiyar *et. al.* [11] presented Improvement in LEACH Protocol for Large-scale WSN by proposing a new energy efficient clustering protocol (FZ-LEACH) that forms Far-Zone. Far-Zone is a group of sensor nodes which are placed at locations where their energies are less than a threshold. It is found that the protocol saves around 30% energy of sensor network in comparison to LEACH. Bakr andek Lilien [4] proposed LEACH-SM protocol, which modifies the prominent LEACH protocol by providing an optimal energy-saving spare management, including spare selection. Dawood *et. al.* [7] presented energy efficient wireless sensor networks based on QoS enhanced base station controlled dynamic clustering protocol. Every sensor is required to make use of the available energy efficiently by modified QoS enhanced base station controlled dynamic clustering protocol.

Wang and Zhu [34] proposed an improved protocol LEACH-R to improve the selection of cluster-head by considering residual energy and distance to base station. It is found that LEACH-R protocol saves around 20% energy of sensor network in comparison to LEACH. Jianyin [10] presented a simulation of improved routing protocols LEACH which takes into account compression ratio, surplus energy of nodes as a pivotal factor in cluster-head node selection to find out the optimal number of cluster heads. Liu and Wu [16] presented improvements in LEACH based on energy of sensor node and the distance between the node and the base station in the forms of LEACH-E and LEACH-ED. LEACH-E considers residual energy of nodes in phase of cluster head selection and LEACH-ED takes into account both the residual energy of nodes and the distance between the base station and nodes. Results of simulation indicate that the improved protocols can balance the network load and prolong the network lifetime. Pawar and Kasliwal [21] presented an Enhanced LEACH protocol (En-LEACH) which is capable to handle non-uniform energy distribution characteristic of a dynamic sensor network. Shi et. al. in [27] presented an optimized LEACH-C in which cluster heads are randomly selected from the nodes with energy above the average, and the simulated annealing algorithm is utilized to find the optimal solution with better position to reduce the energy loss of cluster heads.

Mantri et. al. [18] presented a scheme in which grouping of nodes based on available data and correlation in the intra-cluster and grouping of cluster heads at the network level help to reduce the energy consumption. In addition, proposed method uses additive and divisible data aggregation function at cluster head (CH) as in-network processing to reduce energy consumption. Cluster head transmits aggregated information to remote sink and cluster head nodes transmit data to CH. Cluster based data aggregation improves the scalability and reduces the energy consumption in aggregation of data. Optimal number of cluster head has a direct effect on energy consumption. Singh and Lobiyal [29] implemented a PSO based technique within the cluster rather than base station, which makes it a semi-distributed approach. The proposed technique shows better performance in terms of network lifetime, average number of packets sent and energy consumption.

Yunjie *et. al.* [37] proposed an k-means based improved routing algorithm LEACH-KED to improve performance of the network by the optimal number of cluster head and the mechanism of cluster head selection, making node energy consumption reduced and extending the network life cycle. Zhao et. al. [38] presented a new version of hierarchical protocol which obtains energy efficiency by the modification to choosing of cluster heads formula and the steady-state phase. The modification to the choosing of cluster heads formula makes the sensor nodes which have more energy and play less role in making the CHs or vice CH (VCHs) have more opportunity to act as CHs in the coming round. So the total energy of the whole network has more even distribution among different nodes. The introduction of VCH makes the frequency of re-clustering more lowly and prolongs the time of being in steady-state phase; thus the energy used for calculating the formula on every node reduces. Raj [23] suggested a new protocol EDRLEACH which is based on using a very equally distributed cluster and decreasing the unequal topology of the clusters. Sharma and Sharma [26] modified LEACH establishing multilevel clustering approach to minimize communication distance between nodes and introduces Master Cluster Heads along with Cluster Heads.

Li and Wang [15] presented the LEACH algorithm in a new version by considering the residual energy of each node in each round inconsistencies in selected path and proposed the concept of the energy threshold and distance factor, energy threshold and distance factors to determine the preferred cluster head collection selected on the basis of the cluster head node to improve node energy utilization. Kaur and Sharma [12] proposed an improvement on LEACH protocol by choosing optimum number of Master Cluster Heads from variation cluster heads present in the network. To minimize the load of the network, minimum number of cluster heads has been elected in each transmission round.

Nikolidakis *et. al.* presented ECHERP which considers the current and the estimated future residual energy of the nodes, along with the number of rounds, that can be cluster heads in order to maximize the network lifetime. The protocol computes the energy consumed using the Gaussian elimination algorithm in order to minimize the overall network energy consumption at every single round. Therefore, it elects as a cluster head the node that minimizes the total energy consumption in the cluster and not the node with the higher energy left, as in many other protocols. ECHERP also adopts a multi-hop routing scheme to transfer fused data to the base station. Anitha and Kamalakkannan [3] proposed an energy efficient cluster head selection algorithm in Mobile WSN (EECHS-MWSN). The cluster-head nodes are selected from the residual energy, lowest mobility factor and density of the node. It is also used that the Gateway nodes are act as an intermediate node to transfer the data to the Base station. Simulation result shows that the proposed protocol gives better performance than LEACH-M in terms of energy consumption, network life time and throughput.

Ahlawat and Malik [1] presented an extended vice-cluster selection approach to improve v leach protocol in WSN by improving v-leach protocol on selection of vice cluster head. The process of vice cluster head selection on the basis of three factors i.e. Minimum distance, maximum residual energy, and minimum energy. The proposed approach improves the network life as never the cluster head will die. As a cluster head will die it will be replaced by it's vice Cluster head. Park et. al. [20] proposed a novel cluster head selection method based on k-means algorithm. It is based on the concept of finding the cluster head minimizing the sum of Euclidean distances between the head and member nodes. This is mainly due to effective selection of the CHs such that the distances between the CH and the member nodes become minimal. Firuzbakht and Bouyer [8] presented an optimal Algorithm based on gridding and clustering for decrease energy consumption in WSN.

This approach emphasizes on increasing network lifetime which reduces data redundancy via clustering algorithms and gridding. The proposed algorithm was derived from clustering and the grid- based routing protocols. It follows the clustering routing protocol in data gathering and tries to optimize energy consumption with identifying sensors that sense same data besides integrating gridding and clustering protocols. Lamine [13] presented a new clustering scheme for wireless sensor networks by balancing the energy load among all the sensor nodes in the network. In EAC scheme, the cluster heads and their members are selected according to two parameters: the remaining residual energy and the distance of member's sensor nodes to theirs cluster heads sensor nodes. This parameters conduct to select the appropriate sensor nodes as cluster heads and nearest sensor nodes as members. By this way the lifetime of WSNs is extended. EAC introduces the energy factor for cluster head selection and distance factor for non-cluster heads to select its cluster head.

Chen *et. al.* [6] presented A Low-Energy Adaptive Clustering Hierarchy Architecture with an Intersection-based Coverage Algorithm in Wireless Sensor Networks. To extend the system lifetime, it used the intersection-based coverage algorithm (IBCA) to address lifetime; its introduction causes sensor nodes to enter sleep mode when not operating. This algorithm can achieve reduced energy consumption in transmission. And then combine IBCA with LEACH architecture to improve system performance. Simulation results show that the performance of the proposed technique performs better than LEACH architecture with phase-based coverage algorithm (PBCA) in terms of energy consumption, number of surviving nodes and sensing areas. By using IBCA, the WSN's sensor nodes are classified into two types, i.e., active nodes, which responsible for detecting data, and the sleep mode nodes, which remain idle. Therefore, the entire system requires less live sensor nodes to cover a sensor field. The nodes to enter sleep mode are determined using IBCA, and do not perform any functions, which reduces energy consumption. Finally, the system is constructed by only active nodes, further reducing the energy consumption of the WSN. On the other hand, IBCA selected a greater number of redundant nodes than did PBCA, the main reason being that, with IBCA, a greater number of sensor nodes can be used for judgment. For this reason, the application of IBCA to the LEACH architecture improves the system lifetime.

Tyagi and Gupta [33] developed Enhanced heterogeneous EHE-LEACH protocol for lifetime enhancement of WSN. It has been observed hat Hierarchical clustering and the node heterogeneity are the two parameters by which the lifetime of WSNs can be enhanced. A fixed distance based threshold is used for the bifurcation of direct communication and cluster based communication in the proposed scheme. Nodes near to the base station communicate directly and those which are far away from the BS use cluster based communication. To evaluate the performance of the proposed scheme two key parameters known as: Half Nodes Alive (HNA) and Last Node Alive (LNA) are selected. By selecting the distance based threshold with the ratio of 1:9 between direct communication and cluster based communication it has been observed that EHE-LEACH has better network lifetime with respect to various parameters in comparison to the other well known proposals such as LEACH and SEP.

Mahmood et. al. [17] presented modified LEACH MODLEACH which tends to minimize network energy consumption by efficient cluster head replacement after very first round and dual transmitting power levels for intra cluster and cluster head to base station communication. In MODLEACH, a cluster head will only be replaced when its energy falls below certain threshold minimizing routing load of protocol. Hence, cluster head replacement procedure involves residual energy of cluster head at the start of each round. Further, soft and hard thresholds are implemented on MODLEACH to give a comparison on performances of these protocols considering throughput and energy utilization. Ahmed and Qazi [2] proposed a Mobile Average Energy based cluster head selection algorithm for mobile WSN; LEACH-MAE. In this paper Basic LEACH protocol has been modified to overcome its shortcomings to support mobility along with the new average energy based Cluster Head selection technique. Simulation in NS2 shows that proposed algorithm improves network life time up to 25 % as well as helps to maintain the equal distribution of energy resource among the sensor nodes. Here energy resource and minimum link breakage have been focused. Network lifetime would be degraded if there is random selection of CHs. Also as the speed of sensor nodes increases there are

more chances of frequent link breakage which lead to quick power failure. Hence in the proposed algorithm it has been observed from the above results that even if the mobility is high there is minimum data loss as compared to LEACH-M as well as the network life time is greater with less energy dissipation. It is concluded that by using some mobility pattern for WSNs, energy dissipation can be minimized and network lifetime can be optimized.

Tripathi et. al. [32] introduced a novel cluster based routing protocol in which, the base station finds the highest energy node among the cluster and mark it as a cluster head for the current time. Thus in the proposed system the energy consumption of various nodes becomes more uniform as compared to LEACHC. Natarajan et. al. [19] developed a energy aware optimal cluster head selection for grouping sensor nodes into the cluster that can reduce the size of the routing table of the each individual node and conserve communication bandwidth. LEACH and PSO are applied for producing energy-aware clusters with optimal selection of cluster head. The selection of a cluster head using PSO minimizes the intra cluster distance between cluster head and the cluster member, and the optimization of energy management of the network. From the simulation results, it is seen that Energy-aware Optimal cluster head selection using PSO approach increases the network lifetime of the cluster in such a way by reducing the total energy consumption than LEACH implementation.

III. SURVEY ANALYSIS AND CONCLUSION

As we have seen in above literature, the researchers have tried to optimize LEACH algorithm in several ways. Many have tried to equally distribute energy to elongate the lifetime of WSN. Besides equi-distribution of energy, equi-spatial distribution of cluster is also important because it directly effects the energy consumption by minimizing the distance between nodes and cluster heads. Many methods are centralized controlled by base station to define clusters heads and clusters but few give decentralized control to sensor nodes in choosing their clusters. In the last two or three years many researchers have started using metaheuristic techniques such as PSO, Simulated Annealing and genetic algorithms which provide better spatial distribution of cluster heads for evenly spacing of cluster heads for better energy efficiency. But these methods have proved to be costly for their long time taking iterations. Some hybrid combination of metaheuristic methods and faster k-means method can be a better solution. One concept that has been less utilized by researchers is balanced load distribution among clusters so that every cluster almost utilizes equal energy and battery can last long. This is the area which demands more attention from the researchers.

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