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ECHA: A Novel Energy Efficient Cluster Head Election Algorithm to Provide Energy-Aware Routing in WSN

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Abstract: ***Wireless Sensor Network (WSN) is composed of several low powered, tiny and cheap sensors deployed over a geographical area to monitor the environment. WSN can be set out in various real time applications like security and surveillance, healthcare monitoring, smart grids, smart buildings, environmental monitoring and industrial applications etc. A WSN includes numerous spatially dispersed sensor nodes or motes that sense the environment, transfer them to a computing device through hoping and processes them to result in useful information. Since motes are low-powered and operate on limited energy resource, prolong usage of same nodes to transfer data may lead to network failure. Clustering provides an efficient technique to increase the longevity of network by efficiently using the residual energy in the motes. We propose a reasonable energy aware routing protocol that implements energy efficient cluster formation through Energy efficient Custer Head Election (ECHA) algorithm that increases the network performance to a greater extent.***

Index Terms**:** ***Clustering, Cluster-head Election, Energy-aware Routing, Energy Efficiency.***

I. INTRODUCTION

WSN can be described as a network of self-configuring sensor nodes (motes) that are deployed over a geographical area. The motes sense, communicate the gathered information and actuate through wireless mode using radio signals. In disparity with MANETS, WSN nodes interact with physical world rather than human where the communication network is implanted in an environment like an industry, a military field, a jungle, etc. Sensor motes sense the real world and accumulate environment information. These are transferred to a base station for processing and the motes are actuated accordingly.

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Each mote has a sensing unit, processing unit, communication unit and a power unit. Sensing unit is comprised of sensors and ADC components to gather physical world and transfer them from analog to digital signals. The processing unit has a memory enabled microprocessor to extract useful data from the captured information. The processor works in three modes namely – sleep, process and idle. The communication unit encompass radio transceiver that sends and receives information to and from other networks / base station. The power unit is usually AA battery or coin batteries or solar panels.

Energy consumption is the major issue in any WSN. When all the motes send data from them to sink using intermediate nodes, resulting in node death due to lack of energy and data loss due to congestion. The problem can be resolved using Clustering. Clustering performs division of motes into small groups called clusters with each group having a coordinator node known as Cluster Head (CH). The sensed information is communicated to the CH which is integrates data from all its sub-nodes and then transfers the same to the base station / sink node.

II. RELATED WORKS

WSN is mainly used to monitor a remote environment where human intervention is impossible. While deploying the sensor nodes over an environment, the nodes have two main functionalities to do, namely – send the sensed data to the sink node and relay the transmitted data from the neighboring nodes [1]. This process of sending the data is achieved through routing mechanism. Routing performs the transmission of data through hoping. The routing protocols in a wireless environment shall be classified based on Network structure as

(i) Location-based
(ii) Data Centric-based
(iii) Group-based and
(iv) Hierarchical-based routing.

Kumar A, Shwe H Wong K and Chong P [2] stated that the location-based routing algorithms or geographic routing work on sending data from source to destination based on the distance between them. Each sensor node will be fixed with a low power localization device like GPS module shall be used to know the location information about its neighbour which is at one hop distance from the corresponding node.

The routing follows a greedy technique that transmits data to the destination by hoping to the node which is closest to the destination. The algorithms include MECN, SMECN, GAF, GEAR, GeRaF, M-GeRaF, SPAN, ALERT, GWRR, LARP, LMR and DECA etc.

Unlike the location-based model that uses localization module that requires additional power, the data centric-based routing protocols proposed by Zia Q [3] follow query based methodology where the destination sensor node communicate with the source by sending queries to it and waits until reply is received, after which the data is being transferred. Popular algorithms like SPIN, RUGGED, Directed Diffusion, SAFE, ACQUIRE and Rumour Routing etc follow data centric approach.

Wohwe [4] defined that Group-based routing technique performs grouping of sensor nodes before deployment, such that each node belong to a particular group. Grouping is usually done based on the location of the sensor. A group consists of collection of nodes that are closer to each other. Algorithms like GBP-WAHSN and GMAR follows this methodology.

Algorithms like LEACH, TEEN, PEGASIS etc follow Hierarchical-based routing provides efficient energy management by maximizing the lifetime of nodes besides providing increased scalability. Clustering plays a major role in this approach [5]. These protocols are classified into three types, namely-

(i) block-based
(ii) tree-based
(iii) chain-based

Block-based is typical cluster-based routing technique where the WSN is divided into clusters. The cluster heads to gather data from the subordinate nodes, aggregates the same and transfers them to the sink.

In contrast with the block-based routing, tree-based routing constructs a tree where the source act as the leaf node with the sink as root node and intermediate sensor nodes being the internal nodes of the tree. The leaf nodes send data to its parent; in turn the parent combines the data obtained from its children and sends to its parent. This fashion continues until the data is received by the root.

Chain-based routing creates two or more sequence type structure with each chain having a leader node. The leader sends the collected data from the members of the chain and transmits them through several hops until it is received by the sink. Increased hoping leads to failure of nodes resulting in breaking up of chain incurring data loss.

Optimized clustering can be achieved through

(i) Fuzzy logic
(ii) Neural Network
(iii) Genetic Algorithm
(iv) Reinforcement Learning and
(v) Swarm Intelligence like Ant Colony Optimization, Particle Swarm Optimization and Bee Colony Optimization.

Fuzzy Logic algorithms like LEACH-FL, CHEF, FCH, SEP-FL and DFLC etc that has

(i) Rule base that contains set of rules to govern the system
(ii) Fuzzification that converts inputs to fuzzy sets
(iii) Evaluation Engine that matches the input set with the rule
(iv) Defuzzification to convert the fuzzy set to crisp set.

Neural network is a complex set of neurons that arrives to a decision based on the hidden relationship between the input parameters.

Genetic Algorithm based routing techniques like LEACH-GA, GABEEC that applies heuristic approach in optimizing the solutions. It undergoes calculation of fitness function that ensures the quality of CH selection which is highly adaptable for many of the NP-Hard problems.

Reinforcement Learning is a special field in Machine Learning where best possible solutions are arrived by generating the current output based on the state of the current input and the output of the previous input. CLIQUE algorithm is a best example of Reinforcement Learning that provides intelligent solution.

Swarm Intelligence is based on the behaviour of social insects or other animal species like ants, bees and particle swarms etc. Ant Colony Optimization (ACO) is a meta-heuristic approach in evolutionary computation that provides approximate solutions for NP-Hard category optimization problems based on the behavioural aspect of ants. ACO finds best path between the source and sink using artificial ants. ACA-LEACH, EBAB, T-ANT and ACO-C etc are ACO based routing algorithms.

Particle swarm Optimization (PSO) is a sub-domain of Artificial Intelligence that uses the intelligence of a swarm of birds. PSO works best when resources are low and tasks are many to complete. The algorithms such as PSO-C, MPSICA, PSO-HC, PSO-ECHS etc search for the optimum path from source to destination with the velocity and position as the main criteria [6].

Bee Colony Optimization (BCO) is optimization protocols that are based on the intelligent behavior of bees. BCO have the capability of auto-solving the problems through artificial bee swarms to find the best way to transmit data from source to sink. Bee Swarm, Bee-Sensor-C, ABC-C are few of the BCO based routing protocols.

III. PROBLEM STATEMENT

Let there be 'N' nodes in a WSN that generate data at R_{DATA} rate assuming that the initial energy of the sensor as IE_N. The problem is to find optimum network flow F_{OPT} of data enhancing the network lifetime by efficient usage of E_N. Prolong usage of the same nodes as cluster heads may lead to node death. Hence, when the energy of a CH, E_{CH} goes below the average of residual energy of the member nodes RE_{AVG}, then voting occurs so as to elect the new CH[9].

VI. PROPOSED ALGORITHM: ECHA

Step 1: Broadcast message from CH to all member nodes.

$$CH \rightarrow E_{REQ} \{ID, E_{RES}, CM_N, DIST_{BS}\}$$

The CH passes a Election Request message E_{REQ} to all the member nodes with ID of the CH, Residual Energy E_{RES} of

CH, Number of Member Nodes CM_N under it and the distance of the CH from the base station $DIST_{BS}$. Step 2: On receiving the V_{REQ} message from the CH, each member node E_{RES} higher than that of the CH shall send an Election Accept message $ELEC_{ACC}$ to the CH with the parameters ID of the self, Residual Energy E_{RES} of the self and the distance $DIST_{CH}$ of the competing member node from the CH.

IF $E_{RES}(MN) > E_{RES}(CH)$ THEN
$MN \rightarrow ELEC_{ACC}$ {ID, E_{RES}, $DIST_{CH}$}
Returns to Wait State
ELSE
Discard E_{REQ}
Return to Sleep State

Step 3: The CH after receiving the $ELEC_{ACC}$ message from the competing member nodes CN, shall select the new CH based on the highest residual energy E_{RES} that has minimal distance to reach BS.

$E_{THRESHOLD}$ = AVERAGE {$E_{RES}(CN)$}
$DIST_{MIN}$ = AVERAGE{$DIST_{CH}$, $DIST_{BS}$}
FOR i in range(1, k) REPEAT
DIST[i, BS] $\rightarrow DIST_{CH} + DIST_{BS}$
IF $E_{RES}(CN) > E_{THRESHOLD}$ AND
DIST[i, BS] < $DIST_{MIN}$
$CH \rightarrow CN_i$
$CH_{HELP} \rightarrow CN\{NEXT\_MAX(E_{RES})\}$

Step 4: The CH will announce the new CH through election winner message.
$CH \rightarrow E_{WIN}$ {ID, E_{RES}, $DIST_{BS}$ }

Step 5: Besides, the CH also computes the helper CH and broadcasts the Elected Helper CH, E_{HCH} message. The HCH that act as CH in case of any failure issues with the new CH before electing the upcoming CH when its $E_{RES} < E_{THRESHOLD}$.
$CH \rightarrow E_{HCH}$ {ID, E_{RES}, $DIST_{BS}$}

If the density of the cluster is more, then two level clustering is followed to stop overloading the CH. This means that two HCH will be elected as Helper CHs, which act as the CH for the sub cluster. The sub cluster is formed by applying convex hull based clustering algorithm based on divide and conquer strategy.

V. RESULTS

The aforesaid algorithm provides an efficient way of selecting cluster heads based on energy. The energy based cluster head selection provides maximum lifetime of the nodes. The algorithm also generates a Helper CH that functions as CH if the energy of current CH goes below threshold. The algorithm not only focuses on the energy of a particular node acting as CH, but also considers the distance of the CH from destination.

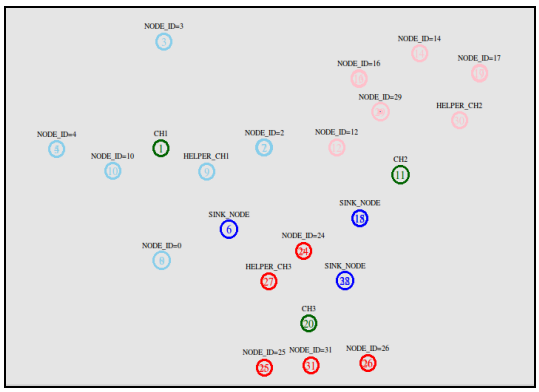

Fig. 1 Initial Node Establishment

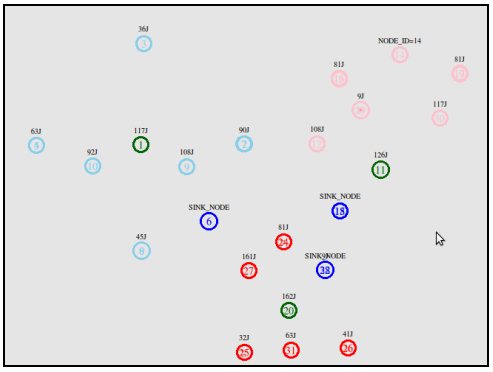

Fig. 2 Residual Energy of Nodes

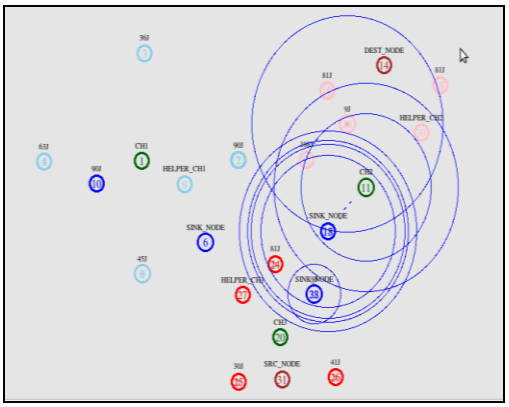

Fig. 3 Election of CH and Helper CH

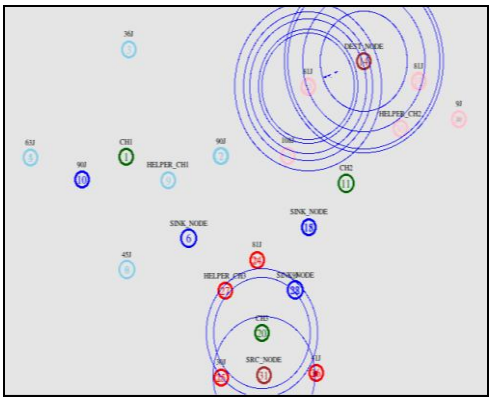

Fig. 4 Nomination of new CH and Helper CH

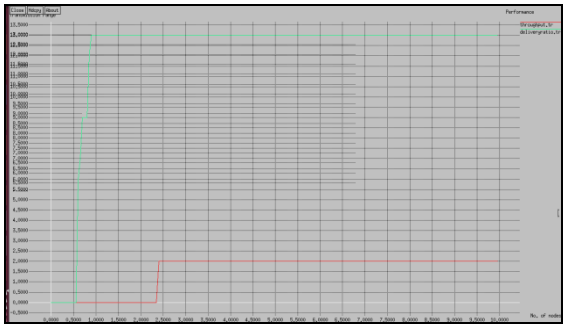

Fig. 5 Performance of ECHA

VI. CONCLUSION

The current work focused on maximizing the lifetime of the cluster head. The CH is selected such that has the maximum energy when compared to all other nodes. Also HelperCH is selected to assist CH when CH loses its energy below the threshold. The results show that the CH and HelperCH are the nodes with maximum energy at any particular point. Further, works can be extended in reducing the number of hops in reaching the destination. Also a soft computing technique shall be applied on the input parameters such as energy, density of nodes, distance etc to increase performance.

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