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EADCR: Energy Aware Distance Based Cluster Head Selection and Routing Protocol for Wireless Sensor Networks

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ABSTRACT: Wireless sensor networks (WSNs) are used to collect data from the surrounding environment. Energy conservation is the most fundamental challenge of WSNs, which primarily depends on cluster head (CH) selection and packet routing strategy. In this paper, an Energy Aware Distance-based Cluster Head Selection and Routing (EADCR) is proposed to extend the lifetime of WSN using the FCM technique, residual energy of nodes, and their relative Euclidean distances from the base station (BS). We propose the protocol and cluster centroid. To avoid this, we introduce a new clustering approach, where the CH selection is now based on a newly proposed fitness function, as nodes consume a considerable amount of energy in the clustering phase. We also propose a new strategy for packet routing using the shortest path technique for routing between a node and its destination that minimizes the energy consumption of CHs by using multi-hop communication. We provide We store the energy of nodes using their Euclidean distance and also from their CH and BS. Simulation results show that EADCR improves network lifetime compared to other similar algorithms express, e.g., FCM, REHR, UCRA-GSO and CCAGWO in different situations. It also saves network residual power and increases network coverage.

KEYWORDS: Wireless sensor networks; FCM; clustering; routing; network lifetime; energy consumption; coverage.

I. INTRODUCTION

Various communication technologies like Internet of Things (IoT), Smart City, Information Communication Technology (ICT), CloudTo effectively balance the load across Cluster Heads: Based on residual energy, ECRP-UCA splits the network into uneven clusters; how far away the sink is; several nodes in the same neighborhood; and an Computing (CC) and BigData (BD) are connected to each other. They are commonly used in healthcare, home and industrial applications, etc.1–3 In current scenario, the drastic advancements in IoT field need deployment of a large number of smart devices, which are connected to each other, e.g., Wireless Sensor Network (WSN)4,5 which is based on the self-organized structure, and consists of enormous amount of randomly deployed sensor nodes having conned energy, restricted memory, and highly integrated circuit.6 WSNs are widely used in military, medical, smart grid and civilian applications, and were primarily employed for monitoring the environment using the sensor nodes.6–11 These nodes are helpful for sensing the environment's condition like temperature, humidity, etc. Such nodes are battery-powered and the replacement of these batteries is not possible in hazardous environment conditions like military, etc.9 Thus, these nodes are having certain limitations like energy consumption, communication range and memory, where reduction of energy consumption is the most fundamental challenge. Since the sensor node consumes a huge amount of energy when its destination is at larger distance, thus the distance-based routing becomes necessary in WSNs.11 Energy-efficient routing protocol governs the optimal usage of energy and provides the intelligent way for data collection among different kinds of devices.

II. RELATED WORK

Related Work Some of the recent research works related to efficient CH selection and routing were reviewed in this section. Moussa and El Alaoui [20] proposed an Energy-efficient Cluster-based Routing Protocol with Enhanced Ant Colony Optimization (ACO) and Unequal Clustering (ECRP-UCA). distance between the current and the next sensor nodes. To address these challenges, Sankar et al. [21] suggested a different cluster formation and Cluster Head (CH) selection technique. There are two stages to the procedure. Initially, by the Sailfish Optimization Algorithm (SOA), the CH is chosen to be called a Swarm Intelligence Algorithm. Next, the Euclidean distance forms the cluster. Previous clustering techniques include issues with the network's short lifespan, imbalanced load among network nodes, and end-to-end delay. Loganathan et al. [22] introduced an Energy Enhanced Routing Protocol (EERP), which is a novel routing protocol utilizing high-efficiency data transfer rules. For creating a fault-free communication model for the WSN environment, the new EERP technique incorporates the scheme's sophisticated clustering logic. With this method, a standard routing structure concerning the base station and sensor nodes is created. The management of CH is the most significant component of a cluster-based wireless technology, as it must be chosen based on specific communication rules, including distance estimation, node capacity, positioning of the base station, and cluster region position. For analyzing the CH and improving the estimation of the pathway process, these restrictions are necessary. To provide an effective CH election process, the presented EERP method makes use of the efficient CH election algorithm Firefly. To increase network energy, Yong et al. [23] introduced a multi-hop routing scheme depending on the path tree.

III. PROBLEM DESCRIPTION

From the above discussion, we found that the various algorithms proposed for the CH selection depend on Eres and the relative Euclidean distances of the nodes. The drawback of the DCHS algorithm is that the energy parameter has not been used for the CH selection process. In EACR-COA, the CH selection depends only on the Eres of the nodes, which was the inefficient use of the node's energy. Similarly, few CH selection techniques considered the Eres and dn2BS, and few others considered the Eres and dn2C. In the FCM algorithm, the CH selection was based on the tens function, which depends on the Eres and dn2C, but not in an efficient way. The packet routing strategy of FCM algorithm does not consider the energy and distance parameter, thus consumes a huge amount of energy. strategy is the same as of the FCM algorithm which is not an efficient use of the node's energy. In UCRA-GSO, the number of CHs changes with upcoming rounds which consume the network energy in an unbalanced way. In CCA-GWO, the concept of relay nodes has been introduced, where each CH sends its data packet to its relay node. These relay nodes directly communicate with BS, where few of them use d4 energy model and consume a huge amount of network energy. In short, the following problems still exist in the WSN, and have been resolved in the proposed work:

- (1) Inefficient CH Selection
- (2) Inefficient packet routing strategy for an intra-cluster communication.
- (3) Huge amount of energy consumption due to inefficient packet routing among all CH.

IV. RATIONALITY OF PROPOSED WORK

In this work, we are saving the energy of the network by employing rotational based clustering approach. The CH selection algorithm depends on dn2BS and dn2C, and extends the network lifetime. In packet routing strategy, we are saving the energy of the nodes in a cluster using the distance-based routing approach, which also saves the energy of the CHs by employing multi-hop communication. Thus, these contributions will prove that our proposed work is beneficial for the WSN. The remaining part of the paper is organized as follows: Sec. 2 describes the problem description and system model, Sec. 3 deals with the proposed work, Sec. 4 deals with the energy consumption in proposed work, Sec. 5 discusses the simulation results and analysis, Nally, Sec. 6 concludes this work.

V. BASIC BLOCK DIAGRAM OF PROPOSED METHOD

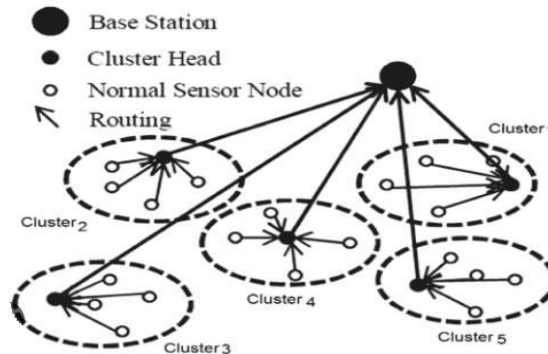


Figure1 BLOCK DIAGRAM

VI. SYSTEM MODEL

NETWORK MODEL

The following assumptions have been considered for our network:

- (1) The network is homogeneous in the beginning, and nodes are static in nature.
- (2) Data aggregation is being performed by every CH.
- (3) Sensor nodes will always follow single hop communication.
- (4) CHs may follow both, i.e., either single hop or multi-hop communication.

VII. CLUSTERING ALGORITHMS

In the recent times, a number of clustering algorithms have been specifically designed for WSNs (Duchene et al 2008) (Anahit et al 2008). The Figure 2.1 shows the classification of clustering algorithms used in wireless sensor networks.

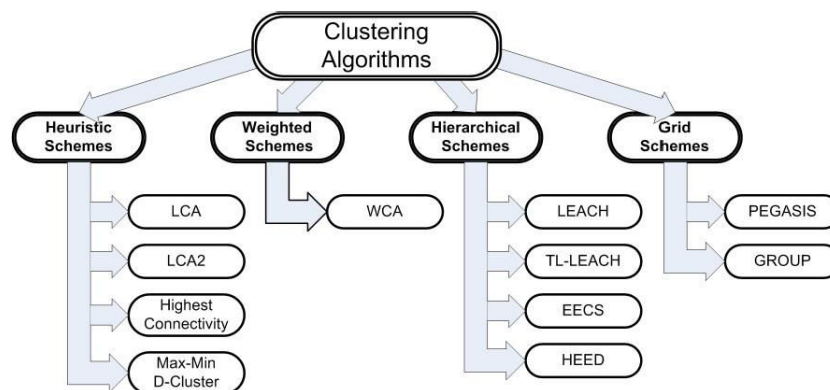


Figure2 Classification of Clustering Algorithms in WSNs

ENERGY DISSIPATION ANALYSIS IN CLUSTER FORMATION

LEACH protocol is implemented in two phases. In the set up phase, cluster head selection and cluster formation takes place and in the steady state phase, the sensing and transferring of a sensed data to the BS through the CHs takes place. When the sensors are far away from the BS, a multi-hop sensor network is more preferable than single-hop communication in order to prolong the network lifetime and thus, multi-hop communication between CHs to a BS is assumed in the analysis.

N sensor nodes are assumed to be randomly deployed in an area of $M \times M$ [m²] and all nodes possess an equal amount of initial energy. LEACH adopts the following energy model. The energy dissipated by a node in transmitting an l-bit message over a distance d is given by Heinzelman et al (2000):

$$E(l, d) = lE_{elec} + ld^2E_{amp}$$

And the energy required to receive the message of l-bits by a node is given by:

$$E(l) = lE_{elec}$$

Where E_{elec} is the energy consumed by the transmitter and receiver electronics and E_{amp} is the energy consumed by amplifier in transmitting system.

A node acting as a cluster member has to sense a desired phenomenon and transmit the same to the cluster head in the allotted time slot. When the nodes

are at one-hop distance, the energy consumed by a cluster head is given by:

$$E_{CH} = E_{oh} + E(l, d) + E_{rx}(l) = E_{oh} + lE_{elec}(E_{amp} + 1)$$

Where E_{oh} is the energy dissipation of a cluster head and member node in cluster formation process during the set-up phase.

Let the number of sensor nodes in a network be N, forming k clusters in each round. Then there are average of $\frac{N}{k}$ nodes in each cluster, k including one cluster head and $(\frac{N}{k} - 1)$ member nodes. Let the initial energy k of each node be E_{init} , the length of data message be l bits, and the length of control message be m bits.

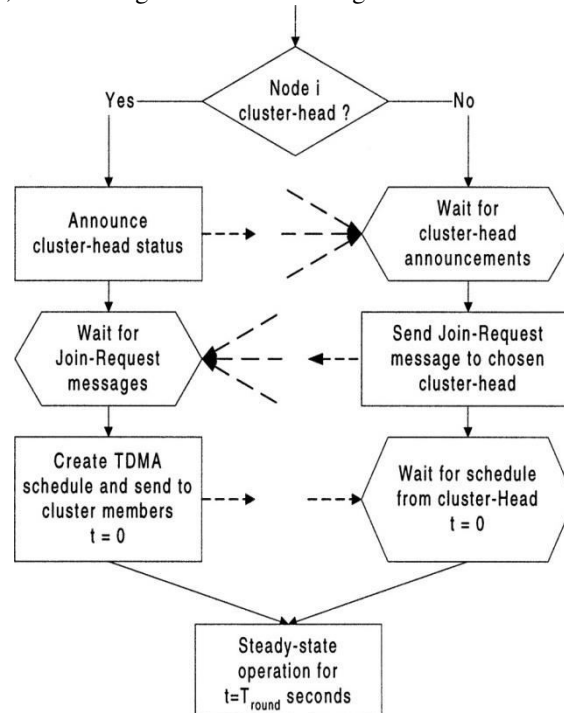


Figure3“Cluster formation process in set-up phase of LEACH protocol”

The cluster formation process in the set-up phase of LEACH protocol is illustrated through flow chart in figure 1.1. In the set-up phase, the energy dissipation of the cluster head node and a member node during cluster formation process is made-up of the following components:

The energy consumption in CH selection process in a node for the next round - E_{CH_Sel} .

The energy consumption of a cluster head node in broadcasting its identity message to the whole network $E_{CH}(BC_Tx)$.

The energy consumption of a member node to receive a BROADCAST message - $E_M(BC_Rx)$.

The energy consumption of a member node to send JOIN- REQ message to its cluster head - $E_{Mem}(J_Req_Tx)$.

The energy consumption of a cluster head to receive a JOIN- REQ messages from its cluster member nodes $E_{CH}(J_Req_Rx)$.

In order to reduce the energy consumption, data aggregation is done by forming a TDMA frame and its time slot is assigned to all member nodes for sending the collected information to the cluster heads. The energy consumed during cluster formation also includes:

The energy consumption of a cluster head to send a TDMA_SCHD message to its cluster member nodes - $E_{CH}(Tdma_Tx)$.

The energy consumption of a member node to receive TDMA_SCHD message from its cluster head - $E_{Mem}(Tdma_Rx)$.

The energy consumed for the above intra-cluster communication during the cluster formation process is given by:

$$\begin{aligned} E(BC_Tx) &= mE_{elec} + md^2E_{amp} \\ E_M(BC_Rx) &= mE_{elec} \\ E_M(J_Req_Tx) &= mE_{elec} + md^2E_{amp} \\ E(J_Req_Rx) &= mE_{elec}(N-1) \\ E(Tdma_Tx) &= (mE_{elec} + md^2E_{amp})(N-1) \\ E_{Mem}(Tdma_Rx) &= mE_{elec} \end{aligned}$$

Therefore, the total energy dissipation as overhead in a node that to become a Cluster head is given by:

$$\begin{aligned} E_{0H-CH} &= E_{CH_Sel} + E(BC_Tx) + E_{CH}(J_Req_Rx) + E_{CH}(Tdma_Tx) \\ &= E_{CH_Sel} + m(E_{elec} + E_{amp}) + m(N-1)(2E_{elec} + E_{amp}) \end{aligned}$$

Therefore, the total energy dissipation as overhead in a node to become a cluster member during cluster formation process is given by:

$$\begin{aligned} E_{0H-Mem} &= E_M(BC_Rx) + E_{Mem}(J_Req_Tx) + E_{Mem}(Tdma_Rx) \\ &= mE_{elec} + mE_{elec} + md^2E_{amp} + mE_{elec} \\ &= (3E_{elec} + E_{amp}) \end{aligned}$$

The total energy consumed by a node is equal to the sum of energy dissipated when acting as cluster head and when acting as a member node. If there are p frames in each steady state of a round and if there is T number of CHs that communicate to the base station via this node when acting as CH; then the energy consumed by a node n at the i^{th} round, is given by:

$$\begin{aligned} \text{Con } E_{0H-CH} + pE_{elec}(d^2E_{amp} + 1)(1 + T); n \in CH \\ E_{0H-Mem} + (E_{elec} + E_{amp}); n \in Mem \end{aligned}$$

From the Equation (3.14), it can be concluded that high frequency of re-clustering will result in more consumption of energy because of increased overhead ($E_{0H-CH} + E_{0H-Mem}$) in CH selection process.

VIII. DISTANCEBASED RESIDUALENERGYALGORITHM

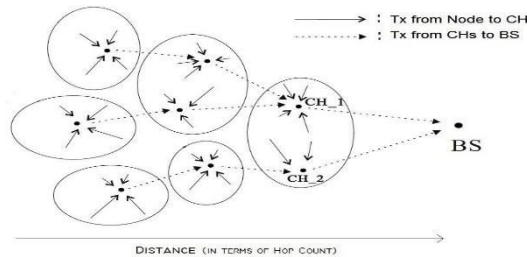


Figure 4 Illustration for estimation of distance between CHs and BS

As the nodes acting as CH which are close to the BS will spend more energy in communicating its own aggregated data and for transferring of the sensed data from other CHs to BS by acting as a rely node, the minimum residual energy in a node to become CH can be made as a function of its distance from the BS. The figure 5.1 shows an illustration of communication that takes place in sending the aggregated data from CHs to the BS.

$$E_{Th}(n) = \begin{cases} E_{Max_Th} - (HC_n \times C) & 1 \leq HC_n \leq 3 \\ 0.6 E_{Max_Th} & HC_n > 3 \end{cases}$$

IX. RESULTS AND DISCUSSION

The simulation of the proposed model requires the MATLAB-2020 simulator and the PC with certain system configurations. The entire simulation of the proposed EADCR model is done in a PC with the 4GB RAM, Windows 10 OS, and the Intel I3 processor. The default values for the simulation parameters. The dimension of the network extends to an area of 100 m × 100 m, and the coordinates of the base station are [50.50]. The scenario-1 includes N=1 00 nodes, the sensing region as 100*100m², Ei =0:5J and Kopt = 5. The BS has been placed outside the sensing region, i.e., at (150, 100) m for this scenario assuming the center of sensing region at (50,50)m. The simulations have been done for evaluating the network lifetime, residual energy and coverage of the network.

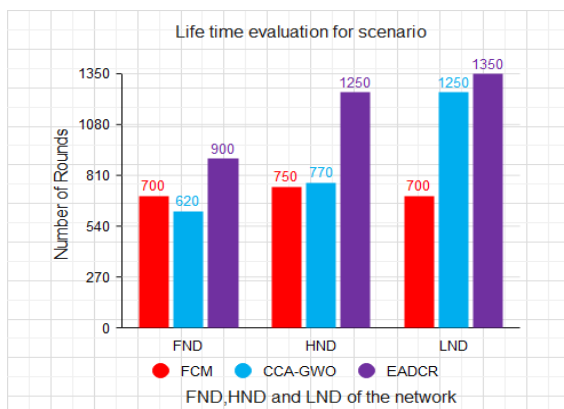


Figure 5 NETWORK LIFETIME

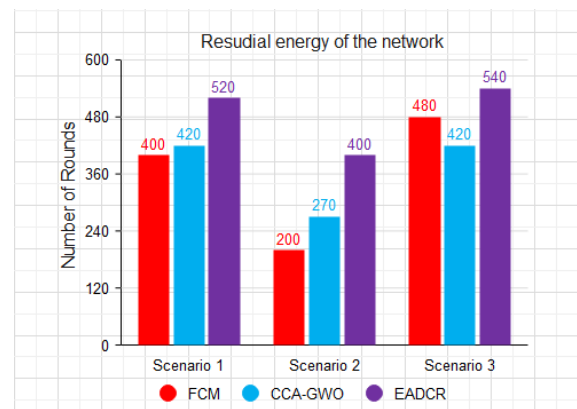


Figure 6 RESIDUAL ENERGY

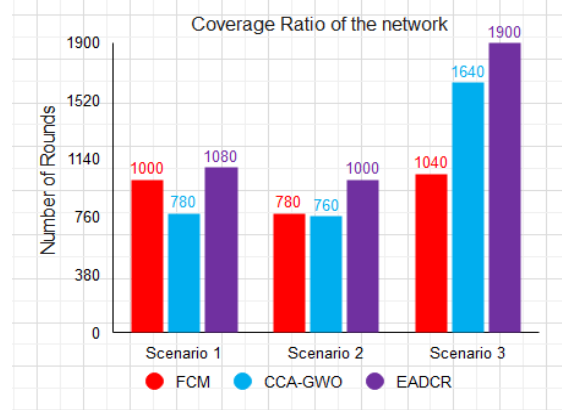


Figure 7 COVERAGE OF THE NETWORK.

X. CONCLUSION

The simulation of the proposed model requires the MATLAB-2020 simulator and the PC with certain system configurations. The entire simulation of the proposed EADCR model is done in a PC with the 4GB RAM, Windows 10 OS, and the Intel I3 processor. The default values for the simulation parameters. The dimension of the network extends to an area of 100 m × 100 m, and the coordinates of the base station are [50,50]. The scenario-1 includes N = 100 nodes, the sensing region as 100*100m², $E_i = 0.5J$ and $K_{opt} = 5$. The BS has been placed outside the sensing region, i.e., at (150, 100) m for this scenario assuming the center of sensing region at (50,50)m. The simulations have been done for evaluating the network lifetime, residual energy and coverage of the network.

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