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An Enhanced Energy-Aware Dynamic Routing Protocol for Wireless Sensor Networks

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Abstract

Wireless sensor network (WSN) becomes a challenging platform where the nodes are used to sense and monitor the target region, and then send the data to the base station (BS) through multihop routing. Because of restricted abilities, the nodes are started to face energy issues and difficult routing process which results in the failure of data transmission and incurs high delay. This paper presents an enhanced energy aware dynamic routing (EEADR) protocol for WSN for load balancing over a larger group of active nodes. The presented EEADR protocol intends to select the gateway node for load balancing over a large set of active nodes thus enhances the network lifetime. The EEADR protocol elects the proper location of the CHs closer to the energy centroid position and for gateway node selection to communicate the data towards the BS via multi-hop transmission. It helps to improve the coverage of CH and reduces the transmission power of CH. In order to investigate the proficient performance of the presented EEADR protocol, a set of simulations were performed and the results are examined under distinct aspects. The obtained experimental results pointed out the betterment of the EEADR technique over the other compared methods.

Keywords: Energy efficiency, Gateway selection, Routing, WSN, CH selection

1. Introduction

Recently, Microelectromechanical Systems (MEMS) have progressively developed and maximum concentration is attained from many developers, wireless communications and in-built digital electronics have resulted in the numerous deployments of microsensors. The tiny sensors are cost-effective with limited energy, multifunctional, and interact freely in a small distance [1]. The sensor nodes are mainly used to sensor, data computation, and data transmission to Base Station (BS) or sink node. It has to perform jointly and develop a

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Wireless Sensor Network (WSN). In general, WSN is comprised of massive sensor nodes used randomly in a coverage region. The nodes are used for collecting local physical data, compute them and forward through sink node. Then, the sink node is connected to the internet for public service. Alternatively, the major feature of WSN is the capability of nodes to perform well. Rather than transmitting actual data, the node is applicable for data fusion, and sensor nodes apply the computational capabilities and determine the fusion operations to send the essential data. Such features of wireless sensors activate them to be applied in most of the coverage region to perform surveillance and observation [2].

WSN is a well-known and effective approach used to predict the environmental difference. WSNs applied for ecological monitoring are composed of massive cost-effective battery-filled sensor nodes, placed in remote and harsh areas [3]. Even though WSN is highly effective, it still suffers from insufficient power resources of sensor nodes. Also, the battery replacement or recharge is impossible as it is placed in the unmanned platform [4]. With the objective of resolving these issues, classical system desires to accomplish maximum Quality of Service (QoS), and sensor network protocols should concentrate on power conservation and expand the network duration [5]. Thus, structure of energy-effective clustering and routing models are considered to be the challenging issues than its comparatives [6].

In WSN, clustering is comprised of collecting the sensor nodes as diverse clusters where a cluster has single leader named Cluster Head (CH). CH is responsible for collecting data from surrounding members called Cluster Members (CM), collect them, and forward them to sink. Every sensor node falls under a single cluster and interacts only concern CH. Hence, CH election has to be performed accurately to manage the power application of CHs; else it experiences premature node death because of the additional overhead for data aggregation as well as data transmission [7]. Mostly, clusters relied on routing approaches to select the CHs and develop into clusters. At this point, a CH is placed in minimum region of a network and ordinary nodes are discriminated and result in network malfunction.

Nowadays, cluster based routing approaches were projected to report the challenging issues of WSNs. Such models are developed to retain the data in network topology, limit the burden of road identification, and mitigate the power application by considering the utilities of the system. Mostly, the applications are energy-based and developed for extending the system duration while some are QoS-based domains. Low-Energy Adaptive Clustering Hierarchy (LEACH) [8] is energy-effective communication protocol and productive routing technique.

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Here, sensor nodes are classified as multiple clusters. In [9], developers have presented a cluster model on the basis of Residual Energy (RE) and distance to BS (DBS). The key objective of clustering is to change the k-means model. In cluster development state, researchers computed the CH election randomly. The distance from sensor node and randomly elected CH nodes are calculated. Additionally, developers of [10] established a distance-energy cluster structure algorithm (DECSA) relied on traditional clustering scheme for LEACH. It concerns the distance from network nodes, the location of BS, and RE of nodes. The main aim of this approach is to divide the system into 3 hierarchies used for reducing the power utilization of CH nodes and results in unequal node distribution. As a result, direct communications among sink and CH could be reduced.

Additionally, in [11], developers have presented Energy-Efficient Clustering Scheme (EECS) for occasional data collecting domains in huge scale sensor networks. In CH election process, numerous CHs are selected by local competition and considers the RE as well as coverage range of candidate nodes. Followed by, in cluster's development phase, weighted function for plain node is established for decision making process where appropriate cluster is unified. Tx amplifier sends the electronics L-bit packet. Moreover, in [12], researchers have presented a partitioning approach for WSN that relied on k-nearest neighbor (KNN). It is used for dividing the network as count of clusters in which a cluster has single BS and sensor nodes can interact directly with sink node. In [13], a model named spectral classification relied on Near Optimal Clustering has been developed in WSNs. It can be operated on the basis of spectral bisection to divide the network into 2 clusters and applies recursively to gain considerable nodes [14-16].

This paper presents an enhanced energy aware dynamic routing (EEADR) protocol for WSN for load balancing over a larger group of active nodes. The presented EEADR protocol intends to select the gateway node for load balancing over a large set of active nodes thus enhances the network lifetime. The EEADR protocol elects the proper location of the CHs closer to the energy centroid position and for gateway node selection to communicate the data towards the BS using multi-hop transmission. It helps to improve the coverage of CH and diminishes the transmission power of CH. A detailed simulation analysis was performed to highlight the effectual outcome of the EEADR protocol.

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2. The Proposed EEADR Protocol

The EEADR protocol has been developed which decides the gateway node to balance the overhead against numerous sets of alive nodes so that the network lifetime can be extended. EEADR protocol is suitable in selecting optimal CH position which is closer to energy centroid and gateway node election is carried out to perform data communication through multi-hop transmission to enhance the CH coverage and reduce the transmission energy of CH. In order to maximize the network performance, the setup platform has been defined and the parameters applied in EEADR protocols like power consumption model, gateway node weightage as well as CH joining weight.

2.1. Network Setup component

In WSN, numerous sensor nodes as well as controller has been applied. The sensor nodes are placed randomly and send the data to CH, which is then transmitted to the BS using single or multi hop gateway nodes which depending upon the distance amongst CH and sink node. Fig. 1 shows the structure of network topology.

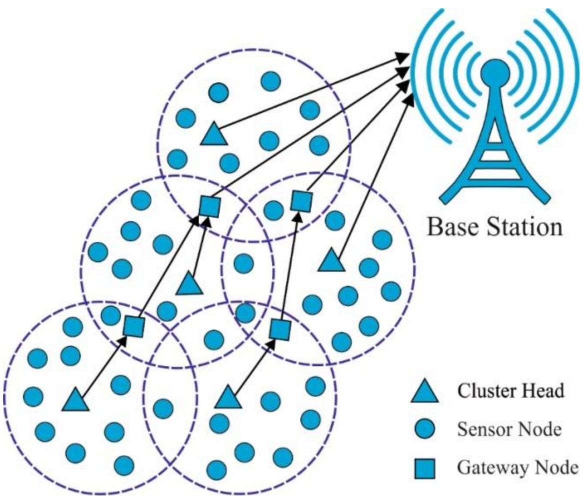

Fig. 1. Network topology

2.2. Energy Consumption Model

Prominent energy consumption takes place in the sensor node, especially in the data transmission and reception [17]. A well-known and general energy mechanism is depicted as follows:

$$E = \begin{cases} l(e_r + e_t + \epsilon_{fs}\ d^2), & if\ d \leq d_{Th} \\ l(e_r + e_t + \epsilon_{mp}\ d^4), & if\ d \geq d_{Th} \end{cases} \quad (1)$$

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Where l denotes the packet size, e_r and e_t indicates the sending and receiving power, $\in_{fs}$ and $\in_{mp}$ are essential to forward in free space as well as multipath, correspondingly. The transmission power utilization is based on distance d.

2.3. Energy Centroid

A centroid is actually a mechanical term that refers the imaginary central point of mass concentration. It can be defined as central point in which mass of an object is determined. The mathematical representation of energy centroid is given below:

$$X_c = \frac{\sum_{i=0}^{n} \left({E_{in}}/{E_o} \right) X}{N} \tag{2}$$

$$Y_c = \frac{\sum_{i=0}^{n} \left({E_{in}}/{E_o} \right) Y}{N} \tag{3}$$

where E_{in} denotes the RE of node i, E_o represents the primary energy, X and Y means the coordinates of node i, N refers the overall count of clusters, X_c and Y_c implies the energy centroid.

The distance between energy centroid location and ith sensor node is calculated using the given expression:

$$d = \sqrt{(X_c - X_i)^2 + (Y_c - Y_i)^2} \tag{4}$$

2.4. Gateway Node

Data gathered to sensor nodes are sent to the sink node which is the major responsibility of CH. Owing to this function of CH and cluster data management, CH observes maximum power and forwards the information directly to sink. Also, nodes available in a cluster that is closer to neighboring CH named gateway nodes. All CH estimates the weight of gateway nodeby concerning the parameters like RE, distance from nodes in certain cluster and adjacent CH is expressed in the following:

$$G(i,j) = \left[\frac{S(i).E}{S(i).Max} \right] + \left[d(i,j)^2 + d(i,x)^2 + d(j,x)^2 + \frac{d(j,s)^2}{d(i,s)^2} \right] \tag{5}$$

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where $S(i).E$ indicates RE of CH, $S(i).$Max depicts initial energy, $d(i,j)$implies distance among $CH\ i$ and $CH\ j$, $d(i,x)$refers distance from $CH\ i$to CM node x which is closer to neighbor $CH\ j$, $d(j,x)$ represents distance among adjacent CH j to CM node x of CH i, $d(j,s)$ defines distance from $CH\ j$ to BS, and $d(i,s)$ signifies distance among $CH\ j$ to BS. A maximum weightage of the node is considered to be a cluster gateway node.

2.5. CH Joining Weight Function

If the CH forwards join request to neighbors, afterward, sensor nodes consider being the portion of cluster. It is comprised of variables like residual energy(Er_i), distance (D_i), and node degree (ND_i)

$$CH\ joining\ weight\ P_i = w_1 * Er_i + w_2 * D_i + w_3 * ND_i\ . \quad (6)$$

Where $w_1 + w_2 + w_3 = 1$.

2.6. CH Selection Phase

Basically, sink telecasts the HELLO-MSG over the system. Hello message encloses BS ID and position. Here, BS contains maximum energy when compared with general sensor nodes, and when the BS is used for broadcasting the Hello messages to alternate sensor nodes so that the burden of CM could be reduced [18-20]. The sensor nodes respond with LOCATION message. The “sender ID” has sensor node ID. Also, “X coordinate as well as Y coordinate” are assumed to be the position of a sensor node. The BS estimates the average energy of a network and estimates the energy centroid location in the system. Once the energy centroid positions are measured, sink node classifies the network as cluster from energy centroid position and CH election is performed. The BS selects a CH node from cluster and is considered to be the closer to energy centroid location. Once the CH election is completed, BS telecasts the FEED-BACK message to certain cluster. The FEEDBACK message encloses this type of message and details of feedback like CH’s ID and average power of WSN. When the first CH election is completed by sink node, CH sends the joining message with CH ID, energy level, and position of adjacent sensor nodes.

2.7. Gateway Selection Phase

A CM receives the CH joining request which evaluates the weight of gateway node. Followed by, gateway node announces the neighboring CH by transmitting the gateway message with position and CH ID which represents the gateway message to requested

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adjacent CH to gateway node. If the closer CH gateway node is received, then it evaluates the route or path of BS through closer gateway node. The data communication of CH by gateway node is based on the distance among them and sink node.

3. Experimental Validation

Fig. 2demonstrates the alive node analysis of EEADR model with existing BEACH, CAMP, and EECRP models under the existence of 2 CHs. The figure depicted that the EEADR has attained improved network lifetime over the other existing methods. At the same time, the EECRP and BEACH techniques have demonstrated minimum network lifetime whereas a slightly improved network lifetime has been obtained by the CAMP model. For instance, on the execution round of 500, a maximum number of 88 nodes are alive by the EEADR technique whereas a minimum of 70, 72, and 75 nodes are alive by the EECRP, BEACH, and CAMP methods. Similarly, on the execution round of 1000, a higher alive node of 8 has been retained by the presented EEADR technique whereas a reduced number of 0, 0, and 0 nodes are alive by the presented model.

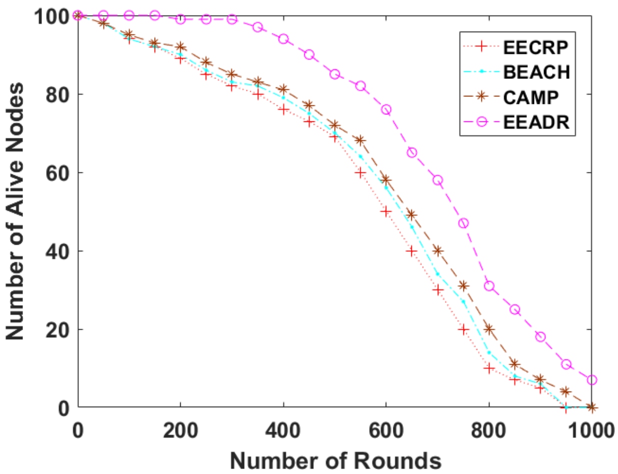

Fig. 2. Alive node analysis of EEADR technique under 2CHs

Fig. 3 investigates the average data transmission analysis of the presented EEADR technique under varying percentage of clusters. The figure demonstrated that the EECRP model has failed to showcased better performance by accomplishing reduced number of average data transmission. At the same time, the BEACH and CAMP models have showcased slightly improved and closer outcome by obtaining a moderate number of average data transmission. At last, the EEADR technique has resulted in an improved performance with the maximum number of average data transmission.

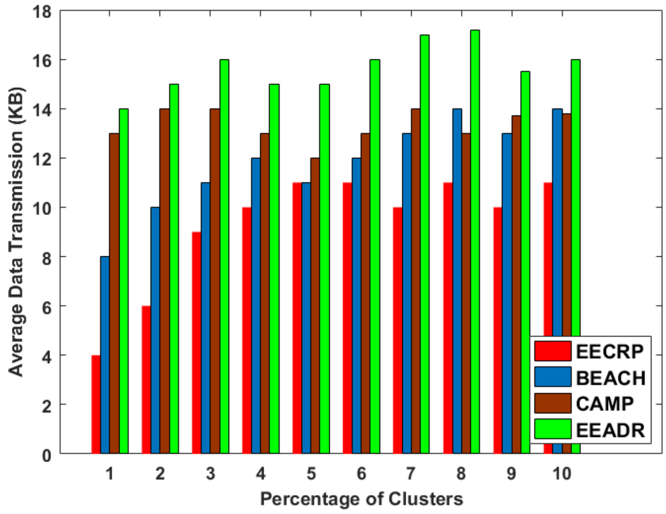

Fig.3. Average Data Transmission Analysis of EEADR Technique

Fig. 4 validates the dead node analysis of EEADR model with the available BEACH, CAMP, and EECRP models under the presence of 2 CHs. The figure showed that the EEADR has achieved enhanced network lifetime over the other existing methods. Simultaneously, the EECRP and BEACH techniques have confirmed minimum network lifetime whereas a somewhat extended network lifetime has been obtained by the CAMP model. For instance, on the execution round of 500, a minimum of 12 nodes are dead by the EEADR technique whereas a higher number of 30, 28, and 25 nodes are dead by the EECRP, BEACH, and CAMP methods. Likewise, on the execution round of 1000, the least number of 92 nodes are dead by the presented EEADR technique whereas a reduced number of 100, 100, and 100 nodes are dead by the EECRP, BEACH, and CAMP methods.

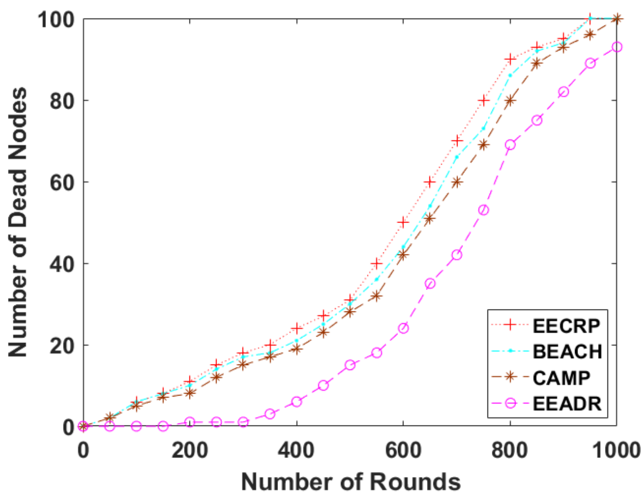

Fig.4. Dead node analysis of EEADR technique under 2CHs

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Fig. 5 investigates the EC analysis of the EEADR model with the existing techniques under the presence of 2CHs. The figure pointed out that the EECRP technique has required a maximum EC over all the other compared methods. Also, the CAMP model has consumed a slightly reduced EC over EECRP model whereas even lessen EC has been obtained by the CAMP model. At last, the EEADR model has required a minimum EC under varying rounds of operation. For instance, under the execution round of 500, the presented EEADR model has required a minimum EC of 25J whereas the other methods namely EECRP, BEACH, and CAMP models have necessitated maximum EC of 60J, 55J, and 51J respectively. Eventually, under the operational round of 1000, the presented EEADR model has retained a considerable EC of 196J whereas the EECRP, BEACH, and CAMP models have completely consumed the 200J.

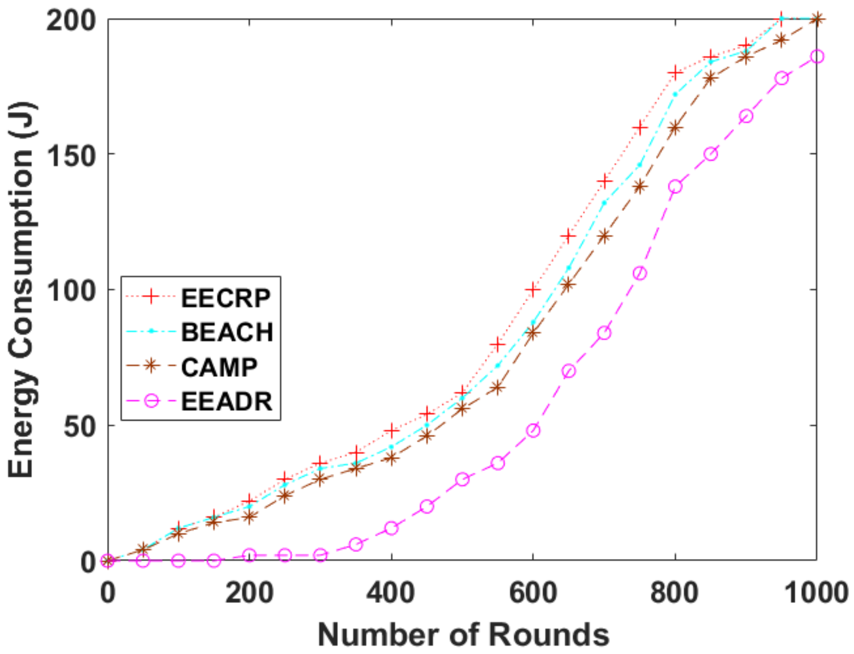

Fig.5. EC analysis of EEADR technique under 2CHs

Fig. 6 performs a brief study of the number of packets received by BS under the existence of 2 BS. The figure demonstrated that the EECRP model has obtained poor performance by achieving a lower number of packets received at the BS whereas the EACH and CAMP models have attained a slightly improved number of packets received at the BS. At last, the EEADR model has resulted in an effective outcome with the maximum number of packets received at the BS. For instance, under the execution round of 500, the EEADR model has accomplished a higher number of 7500 packets received at the BS whereas a reduced number of 7200, 7000, and 6500 packets are received at the BS by the CAMP, BEACH, and EECRP models respectively. Besides, under the operational round of 1000, the EEADR model has gained a higher number of 32500 packets received at the BS whereas a minimal of 30000, 29500, and 27000 packets are received at the BS by the CAMP, BEACH, and EECRP models respectively.

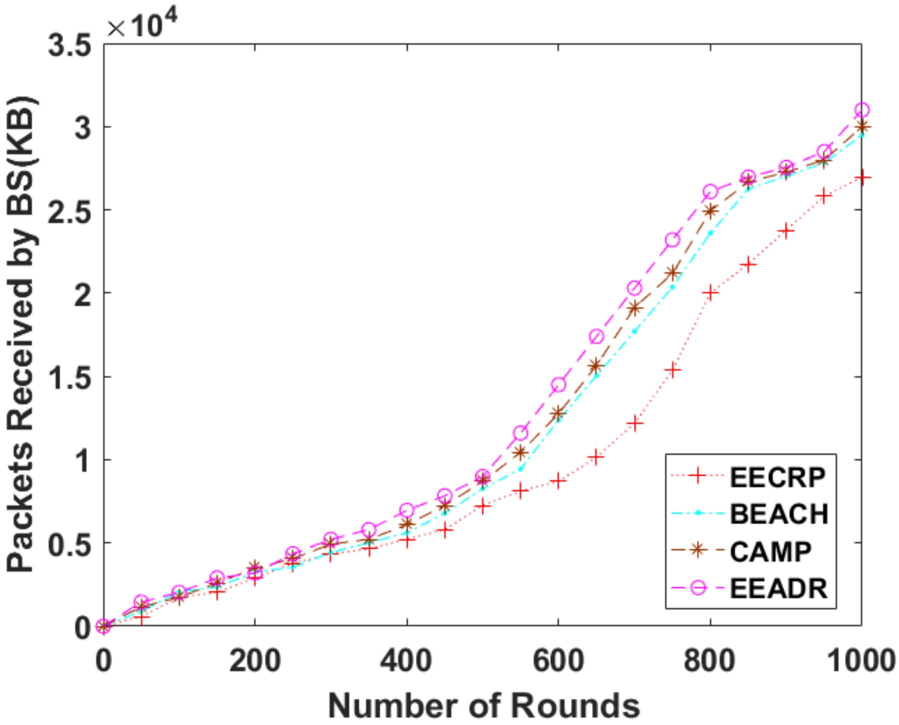

Fig. 6. Number of packets received by BS under 2 BS

4. Conclusion

This paper has presented a novel EEADR protocol for WSN for load balancing over a larger group of active nodes. The presented EEADR protocol intends to select the gateway node for load balancing over a large set of active nodes thus increases the network lifetime. The EEADR protocol elects the appropriate location of the CHs nearer to the energy centroid position and gateway node selection to communicate the data to the BS via multi-hop transmission. The experimental results showcased the effectual outcome of the EEADR protocol interms of EC, network lifetime, number of packets received at the BS, and number of packets transmitted. In future, the performance of the EEADR protocol can be enhanced using unequal clustering techniques.

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