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An Energy Efficiency Distributed Routing Algorithm based on HAC Clustering Method for WSNs

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Abstract

The main objectives of WSNs are to reduce the consumption of energy in its application. The optimistic way of using battery may increase the life time of sensor nodes and it helps improve the performance of the WSNs. To achieve this, in this paper proposed a new hierarchical routing algorithm with high energy efficiency named EECA which is constructed cluster by using distance and residual energy. For cluster construction, first step for electing a cluster head. For this, calculating distance and residual energy of all nodes in a one hop neighbor which helps to select cluster head by using CH rotation. From those results, new CH would be elected. The performance of EECA is compared with AODV protocol by using NS2 simulator. The simulation results disclose that EECA outperform than AODV in energy efficiency, delay and packet delivery ratio.

Keywords: Cluster Head, EECA, Threshold Value, WSNs

1. Introduction

Wireless Sensor Network (WSN) is a collection of micro sensor nodes for an intelligent autonomous monitoring system with communication and computing capabilities that are deployed to monitor the areas. It holds the potential to revolutionize many segments of our economy and life, from environmental monitoring[1]. WSN is one of the most important information access platforms, and it is always deployed in extreme environment where people could not survive to obtain information. A WSN is designed to perform a set of high-level information processing tasks such as detection, tracking, or classification. WSNs can be applied in multiple fields such as military, agriculture, traffic, industry, and environmental protection, and it is one of the most important research topics in computer fields[2]. There should be one or a few sink nodes and a number of sensor nodes in WSNs. WSNs should be having a contact with a base station. All sink nodes communicate with base station. Sink node's energy is supplied by cable, and it should be unlimited; sensor node's energy is supplied by battery and it is limited. If some sensor nodes' energy is exhausted, information from the area monitored by these nodes will not be obtained. And dead nodes will not relay data from other nodes; thus, other sensor nodes will be increasingly burdened with transmission. Given these issues, energy consumption in WSNs is an important research spot. So raising the sensor node's energy efficiency is an important factor to improve the performance of WSNs. Many researches focus on modifying the sensor node's energy efficiency, and designing an efficient routing algorithm is one of the most important approaches[3].

There are three kinds of routing algorithms about energy efficiency in research: data centric routing algorithm, hierarchical routing algorithm, and location-based routing algorithm. A data centric routing algorithm improves energy efficiency by employing short metadata descriptions in advertisements of the availability of data[4]. Data centric routing algorithms find and update the routing information at the same time of transmitting the

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message. This kind of algorithm has many advantages: (i) simple architecture, (ii) easy to be deployed, (iii) strong self-organization ability, but these algorithm has a major problem such as (i) flooding mechanism to transmit information (ii) overhead control packets, this kind of routing algorithms are mostly used in small scale of WSNs[5,6]. The location-based routing algorithm uses location information to guide routing discovery and maintenance as well as data forwarding, enabling directional transmission of the information and avoiding information flooding in the entire network. This algorithm has the advantage as the route would be found very quickly, and the routing information would be accurate, but its efficiency is highly influenced by the geographical environment of WSNs[7]. Chung Horng et al[9]. discussed about the HAC Hierarchical Agglomerative Clustering for the wireless sensor network. HAC is a conceptually and mathematically simple clustering approach. HAC has two important categories, divisive and agglomerative. Data types could be either quantitative or qualitative. Resemblance coefficient also has two types, dissimilarity coefficient and similarity coefficient. An input data set for HAC is a component attribute data matrix. Components are the entities that we want to group based on their similarities. Attributes are the properties of the components.

2. Hierarchical Agglomerative Routing Algorithms

Hierarchical routing is the procedure of arranging nodes in a hierarchical manner. It is one of the most popular researches in WSNs, and many typical algorithms are proposed. In this algorithm sensors are divided into several groups based on some characteristics called as cluster. In every cluster, there would be a selected node acts as Cluster Head (CH) which is responsible for collecting data from other nodes in a cluster. All other nodes are called slaves nodes are member nodes. Every cluster head has a connection with the base node or sink node. It will manage every data collected from every cluster head data in WSN. This kind of algorithm has advantages as it is robust and strong and the energy of every node is well balanced. But this algorithm has major limitation such as selection of Cluster head.

In this paper, a new typical hierarchical routing algorithm is introduced. This algorithm named EECA (Energy Efficiency Clustering Algorithm) is proposed. The clustering on nodes would be based on initial energy, residual energy of nodes, and distance between the nodes. Generally the distance between two nodes is calculated by the following formula in Equation (1).

$$D_{ab} = \sqrt{(X_a - X_b)^2 + (Y_a - Y_b)^2} \tag{1}$$

X_a – X axis value of the node A. X_b – X axis value of the node B. Y_a – Y axis value of the node A.

Y_b – Y axis value of the node B

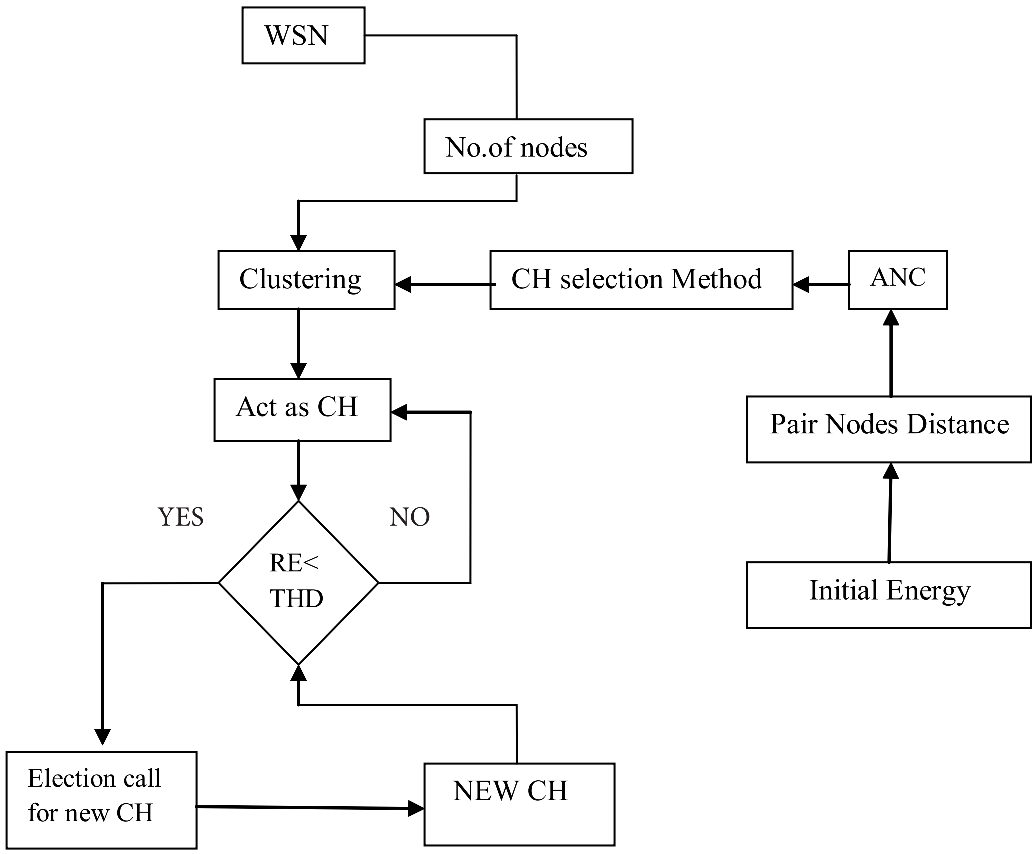
Clustering method based on the two communication phases, that clustering must support inter and intra communication among the several clusters in a WSN. The inter and intra communication phases were described in 3.2 and 3.3 section.

2.1 Data Flow Diagram

Data flow diagram shows the flow of operations in a proposed algorithm works. The collection of nodes is WSN. A data-flow diagram (DFD) Figure 1 is a graphical representation of the “flow” of data through an information system. DFDs can also be used for the visualization of data processing (structured design). A DFD provides no information about the timing or ordering of processes, or about whether processes will operate in sequence or in parallel. It is therefore quite different from a flowchart, which shows the flow of control through an algorithm, allowing a reader to determine what operations will be performed, in what order, and under what circumstances, but not what kinds of data will be input to and output from the system, nor where the data will come from and go to, nowhere the data will be stored (all of which are shown on a DFD). It is split into multiple clusters according to its residual energy aware distance. In each cluster CH needed to transmit the data of cluster nodes. Available nodes in clusters its details are included in the Available Nodes in Clusters (ANC) special packet for transmission. Initial CH act as CH up to its residual energy reaches its threshold energy. If not reaches it will continue the CH position else it will call CH selection method.

2.2 CH Rotation Method

A new CH selection and rotation method is proposed, that initially the centroid value nodes of each cluster act as CH for its own cluster. In a cluster the centroid node owning CH position up to its residual energy reaches the threshold level. If its residual energy reaches threshold level it would be send election call method packet to every node in a cluster.



CH - Cluster Head.
RE - Residual Energy.
THD - Threshold.
ANC - Available Nodes in Cluster.

Figure 1. Data Flow Diagram of EECA.

CH rotation method uses the Chebychev Distance formula to calculate the CH with energy aware distance. The formula is shown in equation (2) and equation (3) is to find the weight of the every nodes.

$$CH = MAX\,(|\,NRi_1 - Wi_1\,|, |\,NRi_2 - Wi_2\,|, |\,NRi_3 - Wi_3| \ldots |\,NRir - Wir\,|) \quad (2)$$

$$Wi_n = \frac{Ri_n + Nd_n}{2} \quad (3)$$

Nd_n - Node distance from CH.
Wi_n - weighted residual energy.
NRi_n - Residual Energy of Node.
Ri_n - Residual energy of node.
CH_{Ri} - Cluster head residual energy.

The above method is used to select the energy aware CH and rotation of CH. Consider the following particular cluster in WSN as an example shown in the following Figure 2.

The initial cluster head selected based on the cendroid value from the cluster. The centroid value calculated using distance between nodes and residual energy of nodes in a cluster. Initial CH is node 4. That node's current residual energy which is would be reached threshold level for rotation method call.

The Table 1 listed the distance between the nodes. The space value node is currently acting as a cluster head. Table 2 shows the current residual energy of the nodes in a cluster after centric node acted as CH. The calculated weighted residual energy for the nodes mentioned in w,

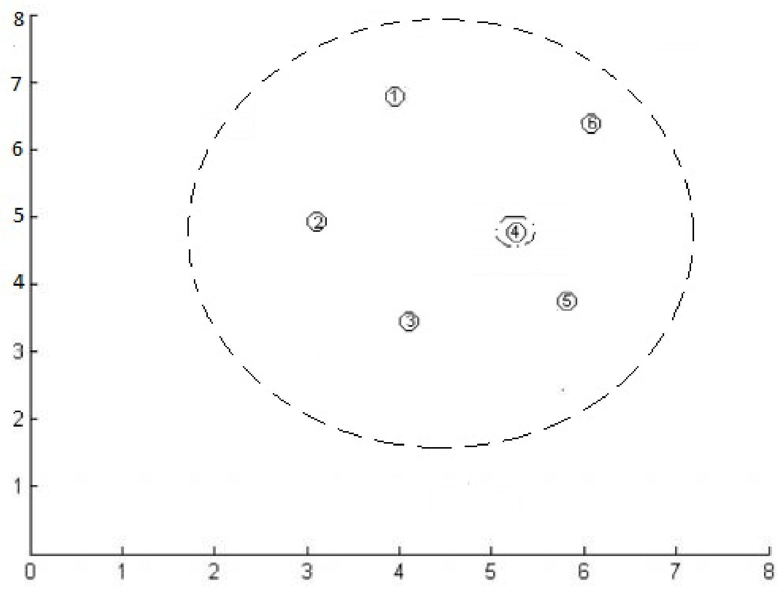


Figure 2. Clustered Nodes and Initial CH in a WSN.

Table 1. Distance between Nodes (Nd) and First CH

Nodes (N)	1	2	3	4	5	6
Ndi	10	12	7	–	4	6

Table 2. Residual Energy of Nodes for CH1 Selection (Rin)

Node ID	1	2	3	4	5	6
Energy	90	85	88	60	95	92

Table 3. Weighted Residual Energy for CH1 Selection (Wi)

Weight	w1	w2	w3	w4	w5
Energy	50	48.5	47.5	49.5	49

and listed in Table 3. The table values are used to calculate the required information values for WSN.

Applying the above values on Chebychev formula, we get the values as shown in Equation (4)

$$\text{MAX}\ (|90–50|, |85–48.5|, |88–47.5|, –, |95–49.5|, |92–49|)$$

$$\text{MAX}\ (40, 36.5, 40.5, –, 45.5, 43) \qquad (4)$$

Answer = 45.5 Corresponding node is 5.

From Equation (4), the values mention the nodes distance with residual energy values except CH node. Equation (4) having the higher value for the node 5. So node 5 will act as a CH after node 4.

2.3 Second CH Selection

The cluster head rotation showed in Figure 3, the circled node is a current selected cluster head node for the cluster.

Applying the above values on Chebychev formula, we get the values as shown in Equation (5)

$$\text{MAX}\ (|82–48|, |75–43|, |81–43|, |52–28|, –, |86–46|)$$

$$\text{MAX}\ (34, 32, 38, 24, –, 40) \qquad (5)$$

Answer = 40 Corresponding node is 6.

The Table 4 listed the distance between the nodes which nodes distances were in need. The space value node is currently acting as a cluster head. Table 4 shows the current residual energy of the nodes in a cluster after centroid

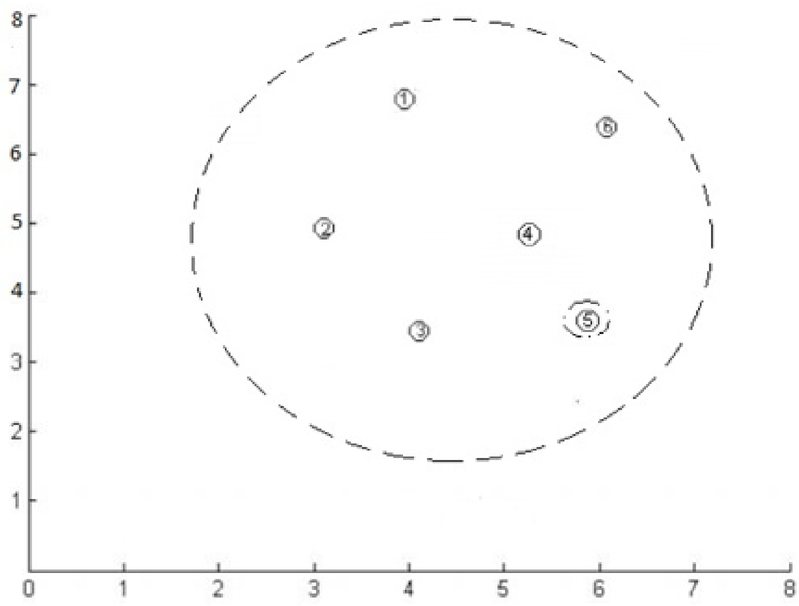


Figure 3. Clustered Nodes and Second CH in a WSN.

Table 4. Distances between Nodes for Second CH (Nd).

Nodes	1	2	3	4	5	6
Nd_i	14	11	5	4	–	6

Table 5. Nodes Residual Energy for CH2 Selection (Rin).

Node ID	1	2	3	4	5	6
Energy	82	75	81	52	75	86

Table 6. Weighted Residual Energy for CH2 Selection (Wi)

Weight	w1	w2	w3	w4	w5
Energy	48	43	43	28	46

node acted as CH. Table 5 values would be less than table 2. Because the nodes energy was used while the first node act as a cluster head. The again calculated weighted residual energy with changed values for the nodes mentioned in w, and listed in Table 6. The table values are used to calculate the required information values for WSN.

From Equation (5), the values mention the nodes distance with residual energy values except CH node. Equation (5) having the higher value for the node 6. Node 6 will act as a CH after node 5.

2.4 Third CH Selection

The Figure 4 shows the cluster head rotation and current cluster head node which is circled over the cluster.

Applying the above values on Chebychev formula, we get the values as shown in Equation (6)

$$\text{MAX}\ (|71-39.5|, |70-42.5|, |74-43.5|, |50-28|, |72-39.5|,-)$$

$$\text{MAX}\ (31.5, 27.5, 30.5, 22, 32.5) \tag{6}$$

From equation (6) Answer = 32.5 Corresponding node is 6. But node 6 already acted as CH so the next value 31.5 would be consider and node 1 would be act as next CH. Like this way the CH selection Rotation method works.

The Table 7 listed the distance between the nodes which nodes distances were in need. The space value node is currently acting as a cluster head. Table 8 shows the current residual energy of the nodes in a cluster after centric node acted as CH. Table 7 values would be less than table 5. Because, the member nodes energy would

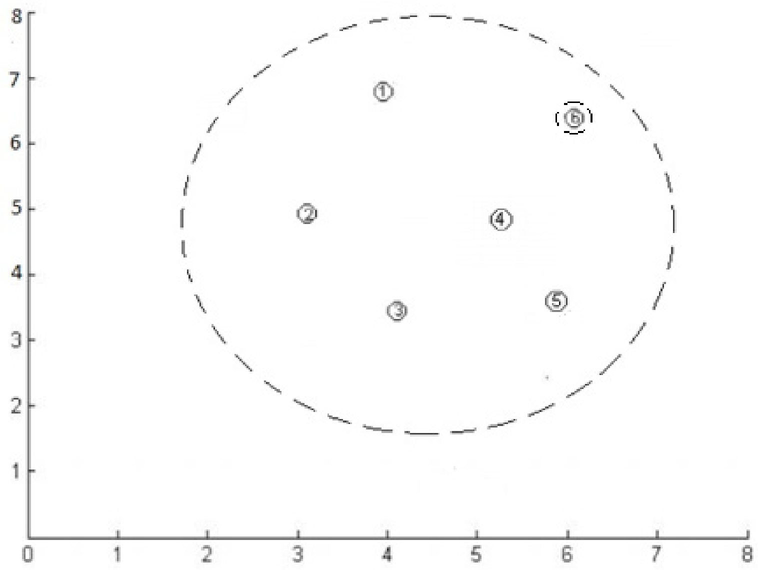


Figure 4. Clustered Nodes and Selected Third CH in a WSN.

Table 7. Distances between Nodes for Third CH (Nd)

Nodes	1	2	3	4	5	6
CH6	8	15	13	6	7	–

Table 8. Nodes Residual Energy for CH3 Selection (Ri_n)

Node ID	1	2	3	4	5	6
Energy	71	70	74	50	72	70

Table 9. Weighted Residual Energy for CH3 Selection (Wi)

Weight	w1	w2	w3	w4	w5
Energy	39.5	42.5	43.5	28	39.5

be used by the previous cluster head nodes. The again calculated weighted residual energy with changed values for the nodes mentioned in w, and listed in Table 9. The table values are used to calculate the required information values for WSN. This method would be balancing the energy of the nodes in clusters. According to node's residual energy and distance, probably nearby energy aware node would be elect as a new CH. This CH selection method is more reasonable it resolve the Hotspot problem in WSN.

2.5 Pseudo Code

2.5.1 *EECA (Energy Efficient Clustering Algorithm)*

Consider each node in the WSN as a cluster S

Compute distances between nodes ∈ S

Compute residual Energy ∈ S

Repeat _ every node met

Compute the distance between each node with residual energy.

Each node merge with the near node and make cluster group based on residual energy distance.

Calculate centroid node using the Manhattan (City block) Distance method with distance and residual energy.

2.5.2 *Distributed CH Selection*

Make centroid node as CH for cluster S.

If (CH energy < threshold) ∈ cluster S

{Send (ID, %energy)

Continue CH position}

Else {Do elect new CH} to cluster ∈ S

Recompute and select CH using current cluster membership

Update_Cluster CH () until the stopping criterion is met

3. Experiments and Simulation

3.1 Network Simulator (NS2)

NS2 is a discrete event simulator targeted at networking research. Ns is a discrete event simulator targeted at networking research. Ns provides substantial support for simulation of TCP, routing, and multicast protocols over wired and wireless (local and satellite) networks. Ns provides substantial support for simulation of TCP, routing, and multicast protocols over wired and wireless (local and satellite) networks.

The proposed system is built on hierarchical routing algorithm. The implementation is a simulation of the proposed system using a network simulator NS2. The effective energy efficient cluster head rotation method is simulated. Hierarchical routing algorithm is a bottom up approach on clustering. The CH rotation selection method successfully simulated based on nodes energy based implementation. The total number of dropped packets is also reduced. In the simulation the CH selection would be showed in a label and the packet transmission moving to sink node. This implementation requires modification to the clustering method and cluster head selection method. The existing code was studied and the places to modify were identified. The parameters which used for the simulation is listed in the Table 10.

Table 10. Simulation Parameters Configuration

Simulation Parameter	Parameter Values
Packet Size	512 bytes
Transmission Range	250m
MAC Protocol	IEEE 802.11
Simulation Time	1000s
Number of nodes	50
Traffic Type	CBR
Sensing Area(m^2)	500*500
Initial Energy of Nodes(J)	90
Threshold Distance(d_n)(m)	60

3.2 Simulation Results

There are two modes available to calculate the WSNs lifetime. In first mode, if any one of the node dead in WSN the entire WSN would be useless. In second mode, the node failure would be measured in ratio, for example if the 30% of the node dead in WSN then network would be useless. The EECA algorithm simulated in ns2 that animated using network animator. The effective energy efficient cluster head selection method simulated. The CH

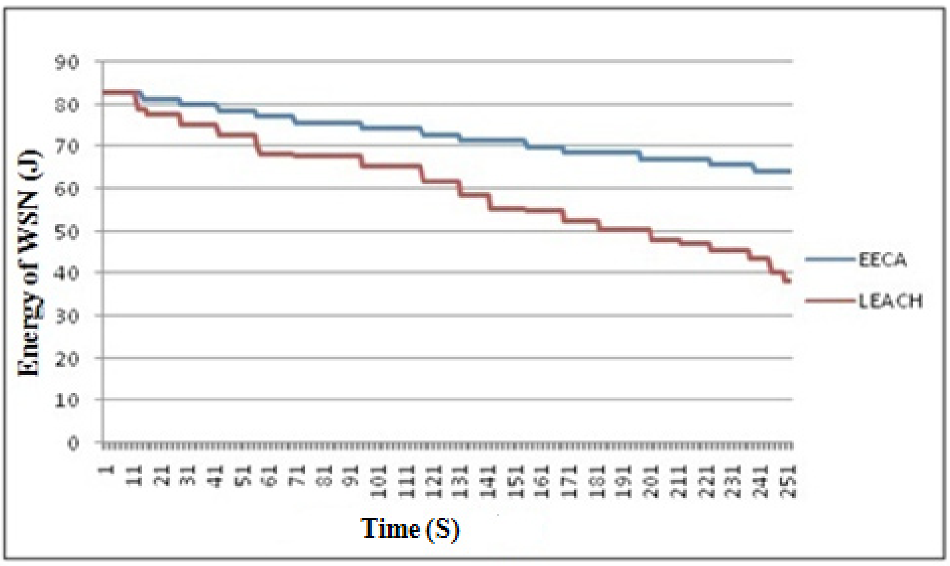


Figure 5. The Lifetime Variability with Energy of WSN.

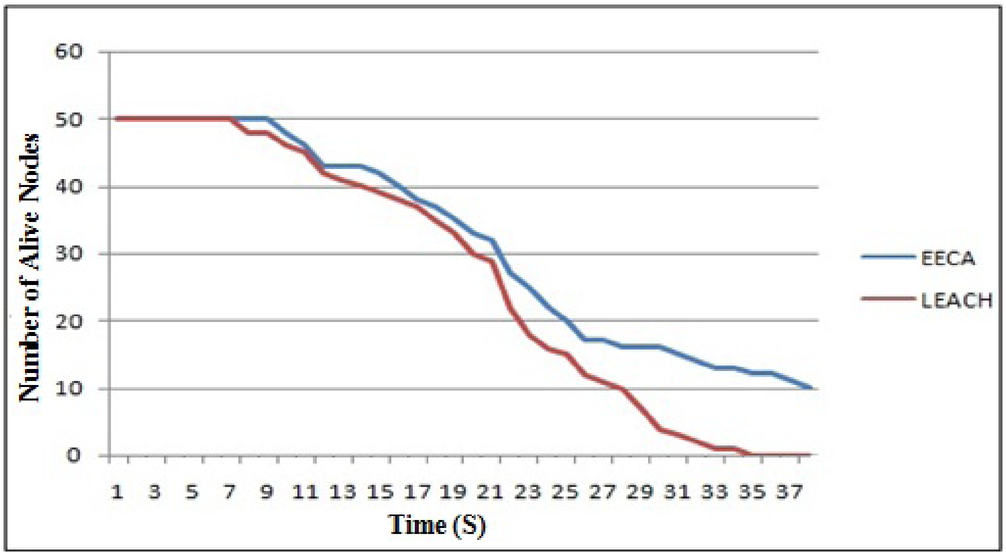


Figure 6. The Lifetime Variability with no. of alive nodes of WSN.

rotation selection method successfully simulated based on nodes energy based implementation. The total number of dropped packets is also reduced.

3.2.1 Lifetime of WSN

According to Figure 5 the lifetime of WSN is compared with the existing LEACH algorithm that shows the energy decrements for the WSN transactions. The energy in joules plotted in y-axis and lifetime in seconds plotted in x-axis .EECA algorithm is having high energy efficiency on clustering and CH selection method than LEACH algorithm, According to result analysis EECA algorithm is having the higher work time than LEACH algorithm for WSNs. That the energy efficiency is high in EECA algorithm, EECA algorithm WSN energy decrement is slower than LEACH. The initial energy of WSN is same in both algorithms. When the WSN starts sensing and transmitting the data to sink node would be uses the energy. EECA is efficiently uses the transmitting mode and energy so its energy decreasing sequence manner. Leach algorithm having the energy decrement is quicker than EECA. From this comparison proposed algorithm having the more lifetime than existing algorithm.

3.2.2 Number of Alive Nodes

The number alive nodes is which nodes are with residual energy in WSN, that the nodes are how long would be alive and transmits the data to the sink node. If more number of alive nodes in WSN would be increase the work time of WSN.

According to Figure 6 the comparison between the two algorithms with alive nodes is shown, the number of alive nodes plotted in y-axis and the time in seconds plotted in x-axis. In initial stages the deployed nodes are alive in both algorithms. When the runtime increases the nodes were dying due to the exhausting energy for transmissions. Because, nodes were have the limited power sources. But energy efficiency method is used to keep the node alive for more transmissions. From Figure 6 the EECA algorithm nodes are dying slower than the leach algorithm. The comparison graph has shown which is having the higher lifetime for nodes in WSN.

3.2.3 Packet Delivery Ratio

Packet delivery ratio is the rate of the data packets sent by the source and the data packets received by the destination. Packet delivery ratio increases when increasing the number of nodes for the following reason: the more the network connections, the better and more available shortest paths towards destination. This implies that there are more connections to connect two nodes offering a better transmission in each region.

Packet delivery ratio for each scenario is calculated in percentage and plotted at y-axis while the number of

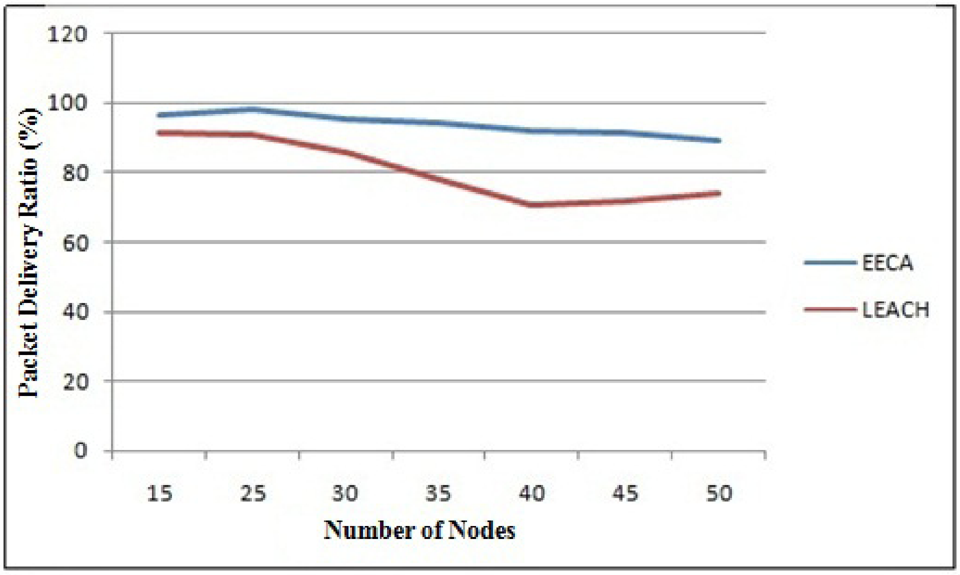


Figure 7. Number of Nodes vs. Packet Delivery Ratio for EECA and LEACH.

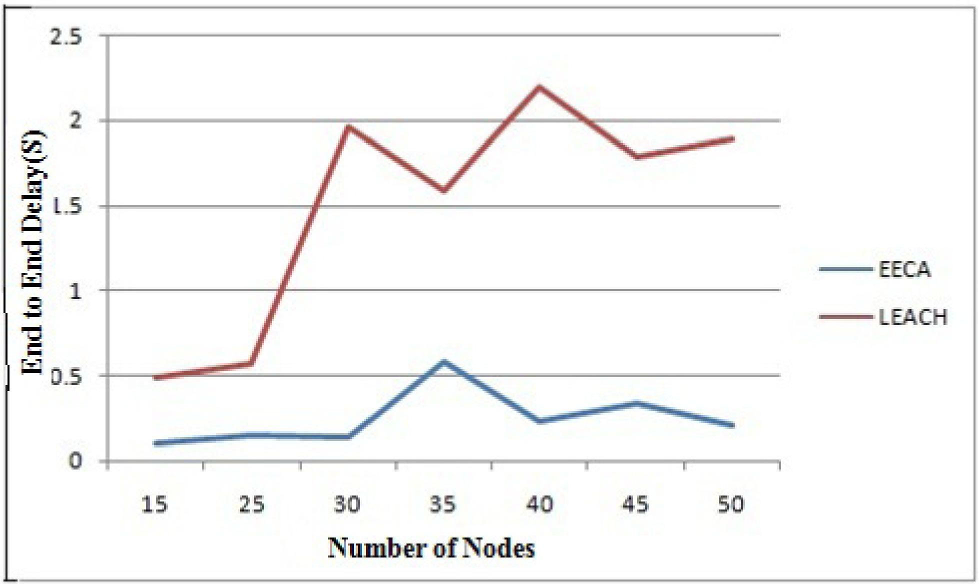


Figure 8. Number of Nodes vs. End-to-End Delay of EECA and LEACH.

nodes is plotted at x-axis. The analysis in number of nodes with respect to the packet delivery ratio for EECA and LEACH is done by increasing the number of nodes. The analysis of the packet delivery ratio in percentage between the EECA and LEACH is shown in Figure 7.

3.2.4 End to End Delay

End-to-end delay refers to the time taken for a packet to be transmitted across a network from source to destination End to End Delay for each scenario are plotted at y-axis while the number of nodes are plotted at x-axis.

When the End-to-End Delay is reduced due to there is decrease in traffic load. The analysis of End-to-End Delay between the LEACH and EECA is shown in Figure 8.

When the number of CBR connections increases the number of collisions, contentions and redundant rebroadcast packets grows, leads to more retransmissions of packets towards the destination and hence resulting in increase delay so LEACH has increased. Delay is the time of the packet taken to reach the destination which is sent by the sender. The collisions and rebroadcast is reduced the delay is low for the EECA.

4. Conclusion and Future Work

To improve the performance of WSN, balancing the sensor nodes energy efficiency is the most important method. “Hot Spot” and “Energy Hole” are two main problems to be resolved to improve energy efficiency and longevity of the network. The project has been designed to attain this goal. It proposes a new algorithm EECA to increase the lifetime of the wireless sensor network. The hot spot problem is resolved in the proposed system by electing cluster head in a distributed manner which is based on the residual energy of each node. In future, the problems related to the distance between CH’s for multi-hop communication would be considered to improve the performance of the WSN.

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