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ECEA-MH: AN EFFICIENT ENERGY-COST, ENERGY-AWARE MULTIHOP ROUTING PROTOCOL FOR MAXIMIZING NETWORK LIFETIME IN WIRELESS SENSOR NETWORKS

MYTHILI D

Department of Computer Science, Hindusthan College of Arts & Science (Autonomous), Coimbatore, India. Email: dmythilimahabal@gmail.com

DURAISAMY S

Department of Computer Science, Chikkanna Government Arts College, Tirupur, India.
Email: sdsamys@gmail.com

Abstract

Network Lifetime of a Wireless Sensor Network is a vital and considered it as a prime parameter. This is also one of the performance metrics to measure the performances of WSNs. In other words, the recently proposed existing Hierarchical Routing Protocols suffering from the premature death of overloaded sensor Nodes which affect the Network's Lifetime. This research work implemented the existing two popular routing techniques namely, Particle Swarm Optimization (PSO) based Low-Energy First Electoral Multipath Alternating Multihop (LEMH) and Grey Wolf Optimizer (GWO). The experimental results of the above mentioned routing protocols were studied thoroughly in terms of Network Life Time, Residual Energy, Throughput, and Average End-to-End Delay. From the experimental results and analysis, this work noticed that the Particle Swarm Optimization (PSO) based Low-Energy First Electoral Multipath Alternating Multihop (LEMH) is performing well in terms of Network Life Time, Residual Energy, Throughput, Average and No. of Surviving Nodes whereas the Grey Wolf Optimizer (GWO) is performing well in term of End-to-End Delay. It was observed that no one Routing techniques were much suitable to improve Network Performances. To address this identified issue, an efficient Energy-Cost, Energy-Aware Multihop Routing Protocol (ECEA-MH) is proposed. The proposed Routing Scheme is developed to avoid overloading the Nodes, and it adaptively changes the contention radius of the Cluster with the topology. This Model combines the remaining energy to vote for those participating in the cluster heads election process. Then, the running Nodes decide the final Cluster Head. This proposed Energy-Cost, Energy-Aware Multihop Routing Protocol (ECEA-MH) is implemented and studied thoroughly. The experimental results of the proposed ECEA-MH is studied in terms of Network Life Time, Residual Energy, Throughput, and Average End-to-End Delay and noticed that it is outperforming as compared with the that of LEMH and GWO.

Keywords: Wireless Sensor Networks, Performance, Multihop Routing, Multipath Routing, Energy Aware Routing

1. INTRODUCTION

Currently, various fields like Agriculture, Environmental Monitoring, Management, Medicine, National Defense, Urban Construction etc is widely adopting the recently developed new generation technologies namely Big Data, Cloud Computing, Cyber-Physical Systems (CPS) and Internet of Things (IoT)[1,2,3].

As far as the various applications concerned, the Wireless Sensor Networks (WSNs) is playing a crucial role in the above mentioned information technologies integration process. The

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Wireless Sensor Networks (WSNs) comprise autonomous wireless nodes which can be randomly distributed and deployed in the network domain. This is employed for collecting various sensory data, such as humidity, light intensity, noise, temperature, and it will forward all the collected information to sink nodes [1, 2, 6, 7].

As far as WSNs concerned, the Energy consumption which mainly occurs in the functions namely sensing the data, processing them, and trans-receive them by considering energy consumption which is performed by the sensor nodes[1,9,10].

Although many Routing Techniques proposed for WSNs have been widely used [1, 11, 15, 19], these techniques fail to address a few issues like short board effect,

There were a few routing techniques proposed and this work analyzed those recently proposed techniques and discussed in the sectioned Literature Survey. Name fo the techniques discussed in the following sections are Hierarchical Routing Protocols, Particle Swam Optimization and Low-Energy First Electoral Multipath Alternating Multihop (LEMH).

The remainder of this paper is structured as follows.

Section II analyzes the previous research results on WSN routing protocols, while Section III defines and elaborates on the proposed Routing Technique, called an efficient Energy-Cost, Energy-Aware Multihop Routing Protocol (ECEA-MH). Section IV presents the experimental setup and the corresponding results. Finally, Section V concludes this work and suggests future research directions.

2. LITERATURE REVIEW

One of the challenges for Wireless Sensor Networks WSNs with the constrained energy is to maximize the network lifetime to perform better and to maximize WSNs performances to improve Quality of Services. This section analyzes the recently proposed clustering and routing protocols namely Hierarchical Routing Protocols, Particle Swam Optimization and Low-Energy First Electoral Multipath Alternating Multihop (LEMH).

2.1 Hierarchical Routing Protocols

The Low-Energy Adaptive Clustering Hierarchy (LEACH) [13] is one of the hierarchical routing protocol, which is designed as to periodically selects the best Sensor Node as a cluster heads by analyzing certain values and levels of parameters. The primary purpose of this is used to achieve Node balancing which will address energy consumption and maximize the network's lifetime too. Therefore, Younis et al. [19] focused to address the uneven distribution of LEACH cluster heads by introducing Hybrid Energy-Efficient Distributed clustering (HEED). How our, it was noticed that it unable to address competition radius which is leading to consume more energy as more cluster neighbor nodes though it is supporting uniform distribution. It is also noticed that this is the protocol designed for single hop communication and it is unable to support for large WSNs. [1, 3, 11, 13, 15, 19]

ISSN 1533-9211
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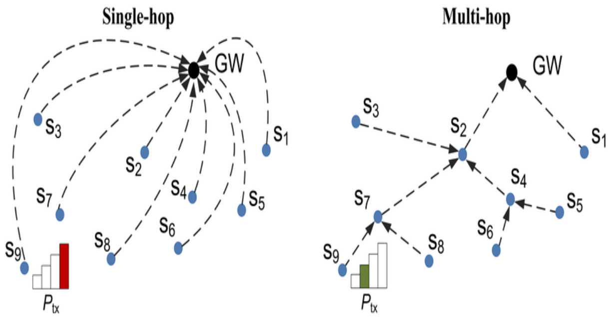

Fig 1: Single vs Multihop Topology

The authors Liu et al. [5, 10] proposed the energy-efficient non-uniform cluster formation algorithm (EEUC), which was regulating the competition radius of Nodes. This is relatively supporting and equalize the CH energy consumption for both the intra-cluster and inter-cluster. However, it fails to address residual energy of nodes. In [12, 13], the authors have focused energy balancing idea to balance intra- and inter-cluster load which hence reduced the excessive energy consumption. This work also employed gradient-by-gradient strategy to minimize the multihop transmission.

2.2 Particle Swam Optimization

Particle Swarm Optimization (PSO) is considered one of the bio-inspired algorithms and it was a simple method for searching an optimal solution. It was different model from that of other optimization approaches. In other words, it is independent from gradient form of objective and it needs objective function alone. This PSO also has a few hyperparameters. From the study, it was understand that this is a meta-heuristic technique proposed by Eberhart and Kennedy [3]). As discussed by the author in his article, sociobiologists believe a school of fish or a flock of birds and was moving in a group "can profit from the experience of all other members". That is when a bird flying and searching randomly for food, it is expected that all birds in the flock can share their discovery and help the entire flock to get the best food. This is the best used to find the maximum or minimum of a function defined on a multidimensional vector space. Let us assume that we have a function f(X) that produces a real value from a vector parameter X. The PSO algorithm will return the parameter X, it found that produces the minimum f(X).

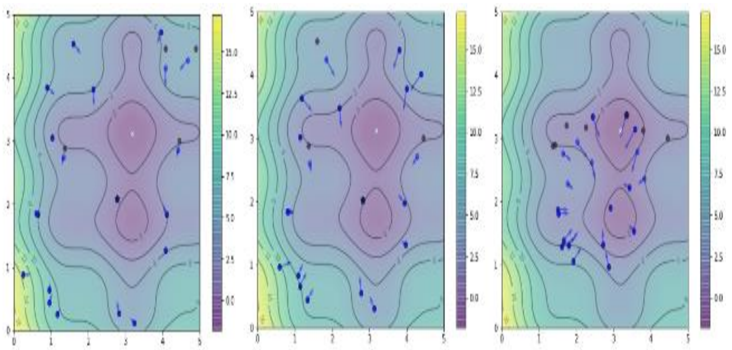

Fig 2: Positions of Participles after 1, 3 and 5 Iterations

ISSN 1533-9211

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2.3 LEMH Protocol

The Low-Energy First Electoral Multipath Alternating Multihop (LEMH) routing protocol is discussed in this section. It is used to protect the low-energy nodes, which processes the sensor nodes effectively and suitably to cover and maximize the network's lifetime. It is capable of adaptively adjusts the conditions of node cluster in accordance with the conditions of the Wireless Sensor Network conditions. This initiative helps to balance the node energy to prevent the premature death of low-energy nodes. Fig. 3 illustrates the LEMH routing technique and its architecture. As shown in the flow chard, all the Sensor Nodes are initialized, and during this phase, the ith node si determines its neighbor nodes and hierarchy hsi. Once all nodes are initialized, they will update their competition radius and competition parameters. At the end, all the nodes run for the finding the cluster head. When the election for finding cluster head is completed, it will execute PSO phase. Each round in this protocol is divided into three phases: cluster head election, cluster formation, and data exchange. Also, the cluster heads are rotated continuously through the election to balance the nodes' energy consumption. The LEMH algorithm considers low-energy nodes. Therefore, we adopt a voting strategy to give more weight to low-energy nodes to select cluster heads that are more affine for most low-energy, aiming to extend the lifetime of low energy nodes. Let si be any one of the participating nodes. si calculates its competitive radius rcsi based on its hierarchy h. Nodes choose their voting nodes based on the competition parameters of the surviving nodes in their competition radius. To prevent nodes with too low energy from having too many votes by weakening the influence of the other low-energy nodes, we specify that a node has a maximum of Max Vote. Each node receives the corresponding number of votes according to its remaining energy Er. The specific vote calculation formula is:

$$Vote\ S_i = min\left(\frac{E_i}{E_r}, MaxVote\right)$$

For updating Normalized Average Neighbor available Energy (NE) with the best competitive radius cluster as shown here.

ISSN 1533-9211
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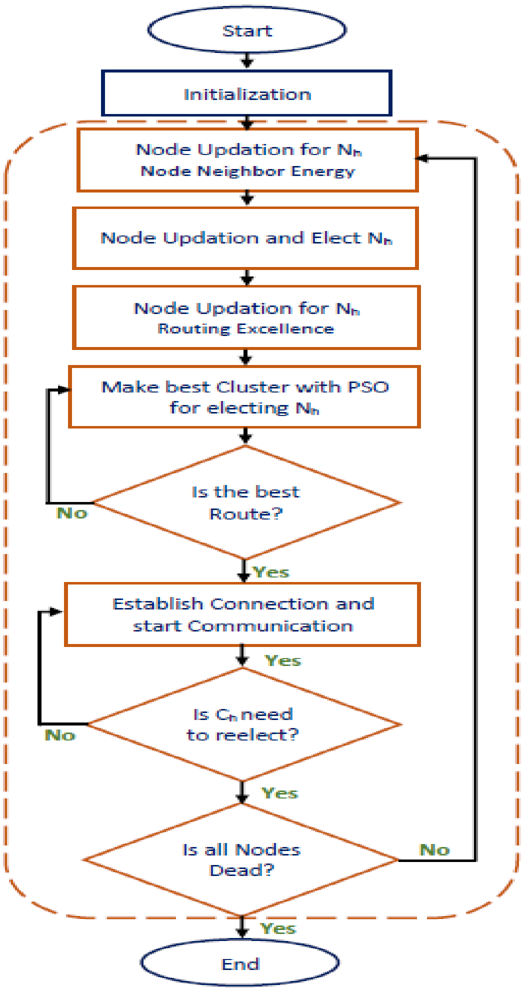

Fig 3: Routing Approach of LEMH

$$r_{c_{si}} = \begin{cases} \dfrac{r_h\,(-\cos(min(NE_i, i)\,.\,\pi) + 1\,) \quad h \leq\; h_0}{2} \\ \dfrac{r_h\,(-\cos(min(NE_i, i)\,.\,\pi) + Crc\,) \quad h \leq\; h_0}{2} \end{cases}$$

Routing Excellence parameter R_i can be calculated as

$$R_i = \sum_{ComInSi} \omega h_{Si}.\frac{d_i ToSink - d_j ToSink}{d_{ij}}$$

The Seybold Report
ISSN 1533-9211
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2.3.1 Algorithm of LEMH

Input: *Assign Sensor Nodes S1, S2..Sn*
Campaign Node Cn
Output: Destination Node Nd
Cluster Head Hc
Initialization
if GNi > 1 then
Broadcasr from Si
while (VoteMsg == 1)
if Bsi = Bhj
Add Si to Sj
else if dij < max(rcsj, csi)
Add Si to Sj.EC
Voting Process
Sn is highest HC
Si vote for Sn
Add voteSi → Sn
else
Add voteSi → Si
Selected Nd
if Votes.Si > Votes.Sn
Si ← Candidate Node
else
Sn ← Candidate Node

Cluster Head Election

If ResponseTime.Sj > T.Time
Remove Sj(Si.EC)
If Si.EC == Null
Si ← Hc
Else
For all Si.EC, Hci > Hcj

3. PROPOSED ENERGY-AWARE MULTIHOP ROUTING PROTOCOL

As we discussed in the previous sections, it was noticed that the Particle Swarm Optimization (PSO) based Low-Energy First Electoral Multipath Alternating Multihop (LEMH) is performing well in terms of Network Life Time, Residual Energy, Throughput, Average and No. of Surviving Nodes. It is also observed that the Grey Wolf Optimizer (GWO) is performing well in term of End-to-End Delay. This research work witnessed that no one Routing techniques are much suitable to improve the Network Performances. To address this identified issue, this research work proposed an efficient Energy-Cost, Energy-Aware Multihop Routing Protocol (ECEA-MH). The proposed Routing Scheme is developed to avoid overloading the

ISSN 1533-9211

DOI 10.17605/OSF.IO/7VGF9

nodes, and it adaptively changes the contention radius of the Cluster with the topology. This Model combines the remaining energy to vote for those participating in the cluster heads election process. Then, the running nodes decide the final Cluster Head. In other words, nominating Cluster Head without overloading by adjusting Cluster radius is an effective approach to maximize the lifetime of the Sensor Networks. This will lead better throughput with relatively less End-to-End Delay.

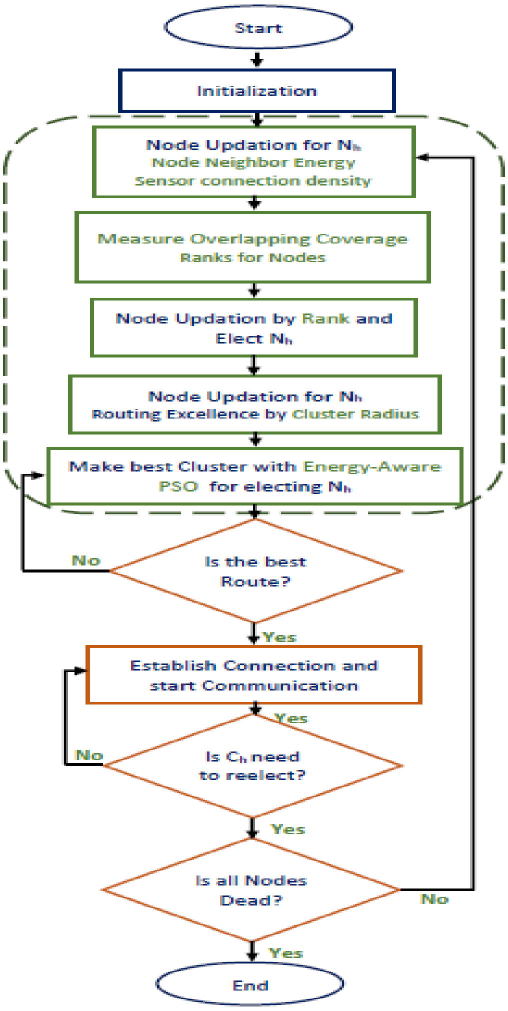

Fig 4: Routing Approach of the proposed ECEA-MH

The metrics focused in this proposed model were residual energy, energy backup, distance between Cluster Head and Base Station, Sensors connection density, overlapping coverage, coverage rate, radius and ranks for Cluster Head to be nominated.

3.1 Routing Techniques of the proposed ECEA-MH

The routing technique of the proposed Energy-Cost, Energy-Aware Multihop Routing Protocol (ECEA-MH) is shown in the figure Fig. 4.

ISSN 1533-9211
DOI 10.17605/OSF.IO/7VGF9

3.1.1 Algorithm of the proposed ECEA-CH

```
Input:  Assign Sensor Nodes S1, S2..Sn
           Campaign Node Cn with Rank
Output: Destination Node Nd
              Cluster Head Hc
Initialization
   if GNi > 1 then
              Broadcasr from Si
   while (VoteMsg == 1)
             if Bsi = Bhj
                       Add Si to Sj
             else if dij < max(rcsj, csi)
                       Add Si to Sj.EC
while (VoteEMsg == 1)
             if Bsi = Bhj
                       Add Si to Sj
             else if dij < max(rcsj, csi)
                       Add Si to Sj.EC.E
Voting Process
   Sn is highest Energy
             Si vote for Sn
             Add voteSi → Sn
   else
Add voteSi → Si

Sn is highest HC
             Si vote for Sn
             Add voteSi → Sn
   else
Add voteSi → Si
Selected Nd
   if Votes.Rank.Si > Votes.Rank.Sn
             Si ← Candidate Node
   else
             Sn ← Candidate Node
if Votes.E.Si > Votes.E.Sn
             Si ← Candidate Node
   else
             Sn ← Candidate Node
```

ISSN 1533-9211
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Cluster Head Election
If Rank.Si > Rank.Sj
Remove Sj(Si.EC)
and
If ResponseTime.Sj > T.Time
Remove Sj(Si.EC)
If Si.EC == Null
Si ← Hc
Else
For all Si.EC, Hci > Hcj

4. RESULTS AND FINDINGS

This Research Work has created experimental set-up and conducted Simulations for evaluating the performance of the proposed Energy-Cost, Energy-Aware Multihop Routing Protocol (ECEA-MH) and the existing Routing Protocol Particle Swarm Optimization (PSO) based Low-Energy First Electoral Multipath Alternating Multihop (LEMH) and Grey Wolf Optimizer (GWO). The experiments were repeated to thoroughly study the efficiency of the proposed model. As shown in the Fig. 5, the Simulation Model was constructed with max of 33 nodes in the each Switch/Router Network and Nodes '6', '20' and '12' are defined as the properties of the multicontroller for adaptive routing.

The Simulation is setup to create different Traffic Rates during simulation Periods and the Maximum Traffic is assigned as 120000 MBs. These Bandwidth was shared by all Functions and for each function, around 1200 MBs is reserved or functions during executions, it may avail maximum of 1200 MBs for its various operations and communications. The simulation has created a Testbed that consists of 10 Hosts with 8 GB RAM and 64 Bit OS.

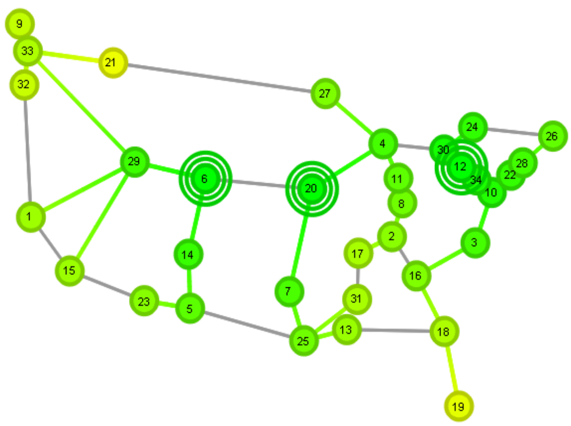

Fig 5: Simulation view of ECEA-MH

This setup can be edited to evaluate the efficiency of the proposed model.

ISSN 1533-9211

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The proposed Energy-Cost, Energy-Aware Multihop Routing Protocol (ECEA-MH) is implemented, and simulated with QualNet 5.0 with the above mentioned properties and studied thoroughly in terms of Network Life Time, Residual Energy, Throughput, Average End-to-End Delay

The experimental results were shown in the Figures Fig. 6 to Fig. 9.

As shown in the Fig.6, the proposed Model maintain relatively more Nodes with adequate energy to making communication. That is, this proposed model maximizes surviving Nodes and Network life time too.

As far as residual energy is concerned, the proposed model save energy and maximizes residual Energy as shown in the figure Fig. 7. As shown in the Fig.8, the proposed Model improves Throughput. As it has focusing best shortest path and cost, the Throughput is maximum and it achieves better End-t-End Delay, which is shown in the Fig. 9

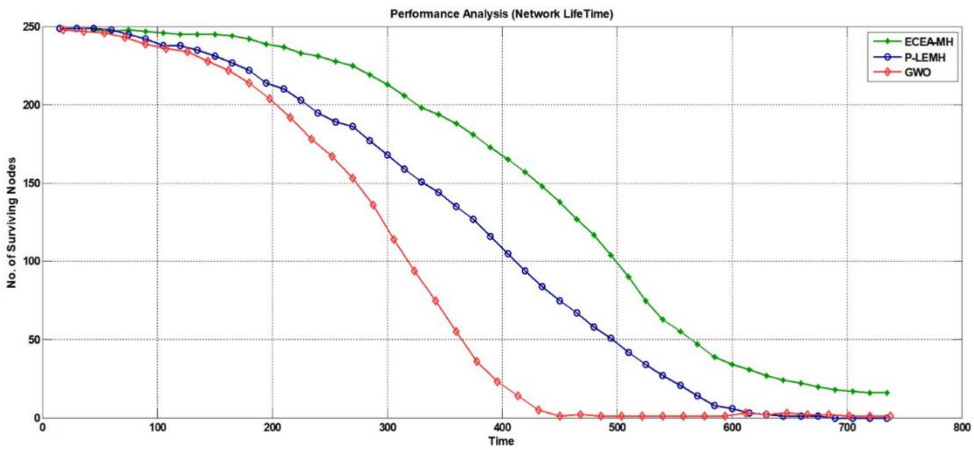

Fig 6: Performance Analysis of the Proposed ECEA-MH: Surviving Nodes

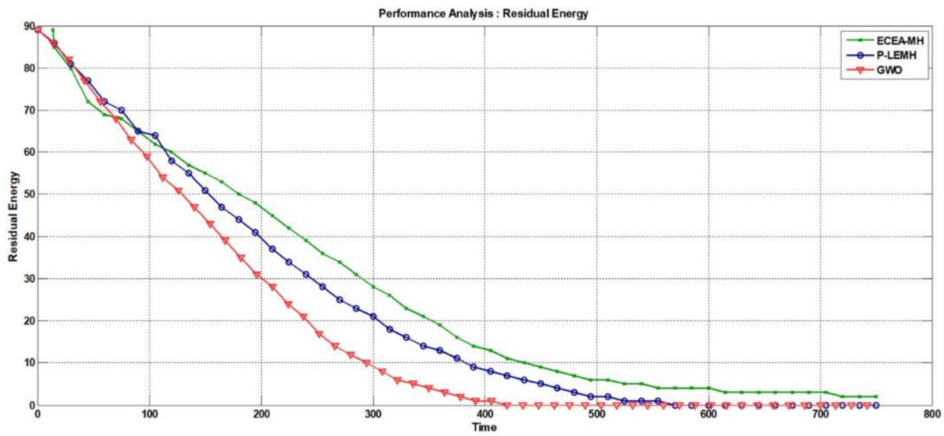

Fig 7: Performance Analysis of the Proposed ECEA-MH: Residual Energy

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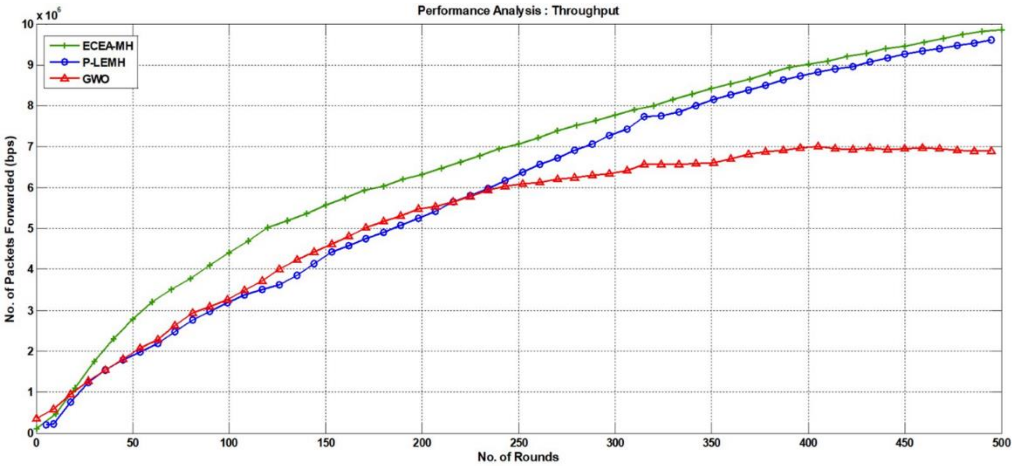

Fig 8: Performance Analysis of the Proposed ECEA-MH: Throughput

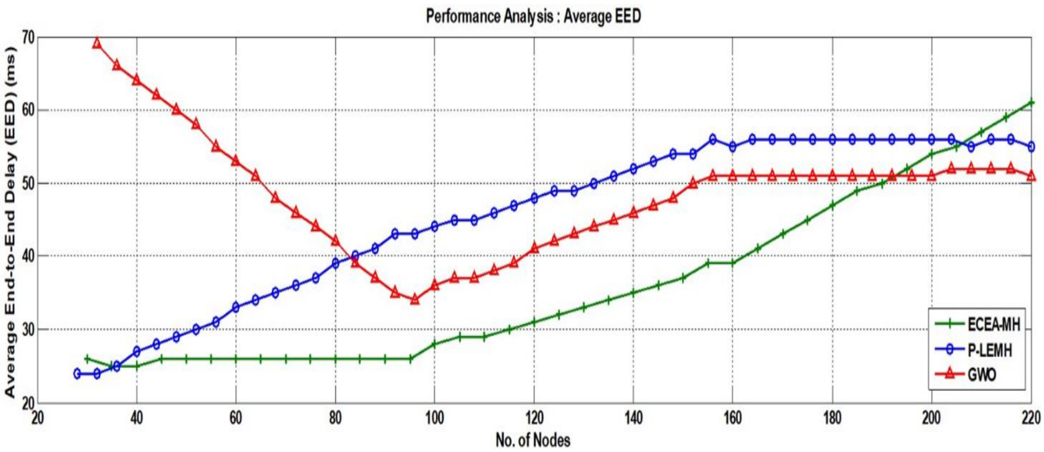

Fig 9: Performance Analysis of the Proposed ECEA-MH: End-to-End Delay

5. CONCLUSION

The recently proposed existing two popular routing techniques namely, Particle Swarm Optimization (PSO) based Low-Energy First Electoral Multipath Alternating Multihop (LEMH) and Grey Wolf Optimizer (GWO) were implemented and studied thoroughly. From the analysis, we noticed that the Particle Swarm Optimization (PSO) based Low-Energy First Electoral Multipath Alternating Multihop (LEMH) is performing well in terms of Network Life Time, Residual Energy, Throughput, Average and No. of Surviving Nodes, whereas the Grey Wolf Optimizer (GWO) is performing well in term of End-to-End Delay. To address this identified issue, an efficient Energy-Cost, Energy-Aware Multihop Routing Protocol (ECEA-MH) is proposed and implemented and studied thoroughly. The experimental results of the proposed ECEA-MH is studied in terms of Network Life Time, Residual Energy, Throughput, and Average End-to-End Delay and noticed that it outperforms better than LEMH and GWO.

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