Optimal Firefly based Balanced Energy Efficient Multi-hop (BEEM) Algorithm in Wireless Sensor Network

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ABSTRACT

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Life time of sensor network is very crucial and hot topic of research in wireless sensor network (WSN) from past to future. It is crucial due to system recharging and replacing the sensors are difficult and costly affair. Clustering provides some solution to extend the network lifetime. Existing clustering algorithms, such as LEACH and other heterogeneous routing protocol, can significantly minimize the power consumption on each sensor and prolong the network lifetime but not consideration of coverage network area. Balanced Energy Efficient Multi-hop (BEEM) algorithm has implemented to simulated WSN network and the selection of the cluster head on the basis of firefly (FF) optimization algorithm. Performance of the proposed hybrid Algorithm is well suited in terms of energy consumptions, stability period, network lifetime, throughput, Alive & Dead Nodes & other parameters. Proposed algorithm has showed improved result in energy consumption with firefly-BEEM over the existing BEEM.

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I. INTRODUCTION

From the last few years, the researchers attract towards wireless sensor networks due to its broad applications and unique challenges. Early study on wireless sensor networks mostly focused on the homogeneous wireless sensor network in which every node contain similar system resource. But, now a day's heterogeneous wireless sensor network is becoming more and more well-liked. Furthermore the results of researches demonstrate that heterogeneous nodes be able to improve network reliability and prolong network lifetime without

considerably increasing the cost. A typical heterogeneous wireless sensor networks has a huge number of normal nodes and a few heterogeneous nodes. The normal nodes a reuse to sense and issue data report, is cheap and source-constrained [1-3].

1.2 Types of resource heterogeneity

a) **Computational heterogeneity:** In this more powerful processor and memory oriented nodes are used. So they are able to do any complicated tasks as compare to a normal node.

b) **Link heterogeneity:** A long distant transceiver is installed with heterogeneous node having high

bandwidth and than a normal node establishes reliable transmission.

c) Energy heterogeneity: It depends on line powered (replaceable battery). The energy heterogeneity is the more significant as computation and link heterogeneity posses more energy [4].

II. Related Work

A large number of protocols researched over a decade to enhance the lifetime associated with the network. This section discusses various protocols that fall under energy efficient category. Low Energy Adaptive Clustering hierarchical protocol [5], [6] (LEACH) is used to enhance energy efficiency associated with the transfer process. Time-division multiple access protocols are integrated within LEACH. Cluster head selection is a major issue within LEACH. Distributed Energy Efficient Clustering Protocol (DEEC) [5], [6] is advance version of LEACH in which cluster head selection is complicated. Firstly, Elected the nodes of large energy in correspondence of all other nodes. The node with the highest probability of conserving energy is considered as the cluster head. Stability Election Protocol (SEP) [7], [8] concentrate the effect of heterogeneity of Clusters in remote sensor area which arranges bunched of nodes. Further, a portion of the nodes proceed toward bunch heads and all the information of cluster is transmitted to the individuals total the information of their group individuals, what's more, transmit it to the sink. It accepts that a rate of the populace of sensor hubs is outfitted with extra vitality assets which are a wellspring of heterogeneity which may come about from the underlying setting or as the operation of the system advances. Remote Sensor Networks (WSNs) [9,10] comprises of across the board arbitrary sending of vitality obliged sensor hubs. The following properties exist in EDEEC. Sensor hubs have a distinctive capacity to detect and send detected information to Base Station (BS) or Sink. Detecting,

addition, transmitting information towards the sink requires a substantial measure of vitality. In WSNs, save vitality and delaying the lifetime of the system are incredible difficulties. Many directing conventions have been proposed with a specific end goal to accomplish vitality productivity in heterogeneous conditions. EDEEC, for the most part, comprises three sorts of hubs in amplifying the lifetime and solidness of the system [11,12].

2.1. Description of BEEM & Firefly Algorithm

In the current technological era, WSN networks are being preferred for the remote location where human cannot visit frequently, so the low energy and low power consumption network are preferred. The efficiency of the network depends upon the type of the routing protocols which provide the path/route for transmission of the data from source to sink [17]. The cluster heads are being used to increase the lifetime of the network. But the choice of the cluster head becomes very important parameter to make the network to consume low power. The optimization algorithm plays very important role in the choice of the cluster head in routing protocols.

2.1.1 Mathematical Treatment for BEEM

The initial energy of the nodes in Balanced Energy-Efficient Multihop (BEEM) is represented by E_0 and the threshold value for the selection of cluster head is represented in Eq 1 as [18]

$$T(s) = p_{opt} / (1 - p_{opt} \left(r \bmod \frac{1}{p_{opt}} \right)) \quad (1)$$

The energy consumption for the transmission of data from source to sink is defined as:

$$E_{tx} = \begin{cases} L * E_{elec} + L * D^2 & \text{if } d < d_0 \\ L * E_{elec} + L * D^4 & \text{if } d > d_0 \end{cases} \quad (2)$$

Where L represents the length of the transmitted packet

The energy dissipation of cluster head is represented as

$$E_{ch} = E_{ch} - \frac{n}{k} E_{nonch} \quad (3)$$

The probability of the nodes in BEEM is as:

$$CH_{prob} = C_{prob} + \frac{E_{residual}}{E_{max}} \times \min(\text{Node Degree} / D_{avg}, 1) \quad (4)$$

C_{prob} is initial probability, D_{avg} is the density of network

2.1.2 Firefly Algorithm

In this algorithm, the solution can be resembled with a firefly and more number of fireflies leads to more optimal solution. In the algorithm, each firefly F_i , in N fireflies has a position X_i in D positions [13, 17]. In the optimum solution, the less brighter firefly move towards more brighter on as presented in equation 5.

$$x_i = x_i + \beta_0 e^{-\gamma r_{ij}^2} (x_j - x_i) + \alpha \left(\text{rand} - \frac{1}{2} \right) \quad (5)$$

Where $\alpha \in (0,1)$ and β both are randomized parameter, rand is the random number, x_i is the position of i^{th} firefly and x_j is the position of j^{th} firefly

2.2 Simulation and Performance Evaluation Parameters

The performance of the proposed routing protocol for wireless sensor network was evaluated on the basis of performance parameters as [14, 15]:

- **Residual Energy:** This is the energy which left after the completion of the each routing process in network as is defined as:

$$T_{Residual_energy} = \frac{\text{Energy_available}}{\text{Average energy Consumed}}$$

- **Packets Sent to Cluster Head (CH):** The number of packets sent to CH destination are calculated as:

$$Packet_{toClusterHead} = \frac{\text{total packet sent}}{\text{total number of packets}}$$

- **Packet to Base Station :** This is main parameter to evaluate the efficiency of the network, it calculate

the total number of data packets sent to the sink or base station/control station and may be defined as throughput of the network.

- **Stability:** This parameter evaluates the stable performance of the network. The WSN network started being unstable with the death of its first node.
- **Network Lifetime:** This is the essential parameter to calculate the overall performance of the network. It is defined as the time period upto which the data being transmitted to the base station. In other words, network lifetime is total time in which the last node of the network becomes dead.

2.6 Methodology of Simulation Analysis

Balanced Energy Efficient Multi-hop (BEEM) algorithm has been implemented to simulated WSN network and the selection of the cluster head has done on the basis of firefly optimization algorithm [16, 17]. The firefly optimization algorithms optimized the election of cluster head and hence reduce the selection time which leads to reduce energy consumption. Ultimately, with the reduction in the energy consumption, the network lifetime of WSN network will be increased. The wireless sensor based network was simulated in MATLAB and the simulations was performed for 100*100 network area with initial energies of 0.3Joules.

Steps:

- 1) Select the Current Hop
- 2) Initialize the firefly
- 3) Calculate the intensity of each firefly
- 4) Movement of firefly based on light intensity
- 5) Rank the current Fireflies and find the best one
- 6) Calculate Next Hop through loop of step 2 to step 6
- 7) Get the optimum route

1.7 Performance Analysis with Proposed hybrid Algorithm in WSN

The performance of the WSN network through optimal firefly-BEEM algorithm was measured through simulation of network field of (100*100) m in MATLAB. The number of nodes deployed in this area was 100 and all nodes are deployed randomly distributed. The size of the packet was considered to be 2000bits for simulation of WSN network. The performance of the proposed firefly-BEEM algorithm was evaluated at different values of the initial energy for various performance parameters. The parameters used for simulation was presented in Table 1

Table 1 : Parameters used for Simulation

S. No.	Parameters	Value
1	Number of nodes	100
2	Network field	(100,100)m
3	Message size	2000 bits
4	E_o (Initial Energy)	0.3J
5	E_{elec}	50nJ/bits

6	E_{amp}	0.0013 pJ/bit/m ²
7	E_{fs}	10 nJ/bit/m ⁴
8	EDA	5 nJ/bits/signal
9	Do (Threshold)	70m
10	Bandwidth	1Mbps

The variant of the initial energy in this case was considered to be 0.3J and the network was simulated for 100 nodes with probability of distribution 0.1. The results of the simulation performed were presented in Figure 1- Figure 4. The stability period of the network in this case was found to be 550 rounds and the network worked well till 1322 rounds as presented in Figure 1 and Figure 4. The maximum number of packets transmitted to cluster head was found to be 98 as shown in Figure 3. The maximum throughput of the proposed network solution was found to be 11642 packets and it lasted till 1322 rounds as presented in Figure 4 reflected the trends for remaining energy of the proposed network and it was found to be lasted till 1320 rounds.

Fig. 1 Stability Period at IE = 0.3J

Fig 2 : Network lifetime at IE = 0.3J

Fig. 3 : Number of Packets sent to Cluster Head at IE = 0.3J

Fig. 4 : Throughput to the base station at IE = 0.3J

Firefly-BEEM at Initial Energy = 0.3 J

BEEM at Initial Energy = 0.3 J

Fig 5 : Comparative Analysis for Stability at Initial Energy of 0.3J

Firefly-BEEM at Initial Energy = 0.3 J

BEEM at Initial Energy = 0.3 J

Fig 6 : Comparative Analysis for Network Lifetime at Different Initial Energy of 0.3J

Fig 7 Comparative Analysis for Packets Sent to CH at Initial Energy of 0.3J

Fig 8. Comparative Analysis for Throughput at Different Initial Energy at 0.3J

The comparison results of proposed Firefly-BEEM algorithm with existing BEEM algorithm for stability period at initial energy of 0.3J were presented in Figure 5. It was observed from the Figure 5 that for all variant of initial energy, the proposed Firefly-BEEM algorithm had more stability period in comparison to existing BEEM algorithm. Figure 6 highlighted the network lifetime of proposed and existing BEEM algorithm and it was found that the network lifetime increased to 1322 in proposed firefly optimized BEEM in comparison to existing BEEM algorithm

where it was 730 for initial energy of 0.3J. The results for the packets sent to CH were presented in Figure 7 and it was found that proposed Firefly-BEEM algorithm performed much better than the existing BEEM algorithm. The results for throughput at different initial energies were shown in Figure 8 and it was observed that the throughput of the proposed Firefly-BEEM algorithm was increased as 11642 packets at initial energy of 0.3 whereas it was very less for existing BEEM algorithm and it was 6762 packets reached at base

station at initial energy of 0.3. The Concluded result has been compiled in table 2.

Parameters	Proposed Hybrid Algorithm Initial Energy–0.3J	BEEM Algorithm Initial Energy–0.3J
Number of Packets to base Station	11642	6762
Maximum Number of Packets to cluster head	98	97
First Node dead at round	550	380
Last node or all node dead at round	1322	730
Energy sustain till round	1320	728
Maximum Remaining Energy	33.0000	32.9584

Table 2. Comparison of Proposed Firefly-BEEM algorithm with existing BEEM algorithm

III. CONCLUSION

The performance of the proposed Firefly-BEEM algorithm was validated by comparing with existing algorithm at different initial energies in this chapter. It was observed from the comparison results that the Firefly-BEEM outperformed the existing BEEM algorithm in all performance measures. The optimum results for proposed Firefly-BEEM algorithm were found to be at initial energy 0.3J in terms of stability, network lifetime,

number of packets sent to CH, throughput and remaining energy of the network.

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