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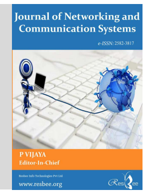

Energy Eficient Routing Protocol in Wireless Sensor Network

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Abstract: "A routing protocol specifies how routers communicate with each other to distribute information that enables them to select routes between any two nodes on a computer network". Routing is a method of choosing a traffic path in a network, or across several networks. Routing is the higher-level decision making which guides network packets via different packet forwarding mechanisms through their source towards their destination via intermediate network nodes. The key contribution relies on routing protocol in which an algorithm named Distance based Monarch Butterfly Optimization (D-MBO) is used. Accordingly, a new multi-objective model is developed with respect to the various measures like "energy, delay, inter cluster distance, distance and link lifetime". Finally, the improvement of the presented method is established over existing models with respect to energy, delay, alive nodes and throughput. From the analysis, the D-MBO model obtains the value of 0.27 which is better than other existing algorithms such as GA, FF and DA in 2000th rounds for delay measures.

Keywords: Routing; Throughput; Energy; Inter cluster distance; Monarch Butterfly Optimization.

Nomenclature

Abbreviation	Description
CH	Cluster Head
CHS	Cluster Head Selection
D-MBO	Distance-based Monarch Butterfly Optimization
EESRA	Energy Efficient Scalable Routing Algorithm
FF	FireFly algorithm
GWO	Grey Wolf Optimization
I-SEP	Improved- Stable Election Protocol
IOT	Internet Of Things
LEACH	Low Energy Adaptive Clustering Hierarchy
MBO	Monarch Butterfly Optimization
MRP	Multi-hop Routing protocol
PSO	Particle Swarm Optimization
QOS	Quality Of Service
WOA	Whale Optimization Algorithm
WSN	Wireless Sensor Network

1. Introduction

WSNs is composed of small nodes with capabilities in sensing, computing and communication. Latest techniques in WSN has contributed for several new routing protocols developed explicitly in network sensor whereby energy is an important architecture problem [6]. The routing protocol is a method to choose the appropriate route from source to destination for the data and travel through it. While choosing the path, that depending upon the type of network, channel characteristics and performance measurements, this system faces numerous challenges [7]. Generally, the data sensed mostly by sensor nodes in a WSN is transmitted to the base station that links the sensor network to the other networks (may be internet) in which the data is being processed, analyzed and any action should be taken as required [8].

Direct communication is often considered as the single-hop communication, while indirect communication is considered multi-hop communication. The sensor nodes not only generate and deliver their material in multi-hop communication and furthermore serve as a path for many other sensor nodes towards its base station [9] [10]. The sensor nodes were also restricted to limited resources themselves,

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so the main goal would be to design an efficient and energy-aware protocol to improve the lifetime of the network for particular application environment [11]. Whereas a single identification and more redundant data gathered at destination nodes are not provided to the sensor nodes. Moreover, the fault tolerance, scalability, latency, energy consumption, accuracy and QOS are several factors that need to be considered carefully when developing the routing protocols in WSN [12].

Obviously it depends about the source to identify a route for the destination; the routing protocols could also be grouped into three types such as proactive, reactive and hybrid [13]. A proactive protocol establishes a routing route and states until demand for routing traffic occurs. If there is no traffic flow at the time, paths were established. Throughout the reactive routing system, once requests are launched the routes were set on demand [14]. Hybrid protocol makes use of these two concepts together. Hierarchical routing is really a guarantee approach with very limited routing state for point-to - point routing. Cloud computing has been one of the sensor network's key design features. Single gateway technology will trigger the gateway to overloaded that might cause a communication split, and therefore it is dangerous to monitor events. Hierarchical routing preserves sensor node energy consumption and executes data aggregation that helps to reduce the information provided to base station [15]. However, the various challenges in routing include energy consumption, node deployment, scalability, connectivity, coverage, security.

This paper deals with the following sections: Section II shows the reviews on routing protocol in WSN. Parameters considered for proposed WSN routing model were determined in Section III. The D-MBO: improved algorithm for optimal routing depicts the Section IV. Section VI portrays the results and their discussions and Section VI shows the conclusion of this work.

2. Literature Review

2.1 Related Work

In 2017, Ramnik et al. [1] have implemented adaptive threshold routing protocol based energy efficient cross layer for WSN. The network clusters were allocated with CH in the principle of weighted probability. For-single sensor nodes the rotating period were similar when measuring the original and final residual energy. A routing protocol in heterogeneous networks was introduced depending on adaptive threshold sensitive contributed energy efficient cross-layer network topology. At last, the experimental outcomes indicated better performance in proposed method than other existing methods.

In 2019, Vinitha et al. [2] have developed Taylor based Hybrid Optimization Algorithm for Secured and Energy Aware MRP of WSN. This system undergoes two phases of MRP namely data transmission and CHS. Originally, the energy-efficient cluster heads were selected using the "LEACH protocol" based on successful transmission of data. Finally, the proposed methods have shown better outcomes when compared to other methods.

In 2020, Ahutu et al. [3] have presented a routing protocol in preventing the wormhole attacks for WSN. Based on low safe facility in WSN, through one point certain malicious nodes were allowed to tunnel packets to another location in order to disrupt the network throughout falling and conducting surveillance packets were really known as wormhole attack. The latest protocols addressed the issue of wormhole attack in seperation from either the consumption of energy by nodes. At last, the experimental outcomes in proposed method indicated superior results than other conventional methods.

In 2019, Ahmed et al. [4] have introduced an EESRA in WSN. The current algorithm's aim should be to prolong the lifetime of the network, disputed a rise of network size. This adopted method with a tri-layer framework reduced the load of the CH and to randomized CHS. In fact, EESRA was developing a hybrid WSN protocol utilizing multi-hop transfers in intra-cluster communications. Finally, the proposed methods have shown better performance than other traditional methods.

In 2020, Behera et al. [5] have established an heterogeneous WSN for routing protocol in IOT. For I-SEP, energy threshold value were determined the CH and their respective cluster would start to transmit over the next stage. The residual energy of the CH-node was assessed after each phase. When the residual energy was below the expected level, the CH election cycle will begin and new clusters would have created. The threshold should preserve a uniform allocation of energy between member and head nodes of the cluster. At last, the proposed method indicated better experimental outcomes than other traditional models.

3. Parameters Considered for Proposed WSN Routing Model

The fitness function can be determined using D-MBO algorithm with various parameters like "energy, delay, inter cluster distances, distance and link lifetime" in which the fitness were measured as a maximization function.

3.1 Energy

"The network energy is defined as the summation of the energies of all hops, which indicates the energy remained in the nodes". Here, Eq. (1) determines the energy.

$$Q = \frac{1}{a}\sum_{t=1}^{a} E(H_t) \quad (1)$$

Where, a indicates the number of hops in MRP and $E(H_t)$ indicates the energy in t^{th} hop.

3.2 Delay

"The delay is measured by using hops that interact throughout the routing, so the delay should be less for efficient routing. The delay was calculated as the ratio of hops required for the total routing nodes in WSN". The delay can be determined by using the Eq. (2).

$$D = \frac{a}{s} \quad (2)$$

Where, s indicates the overall nodes of WSN and a denotes the overall hops in routing.

3.3 Inter-Cluster Distance

"The ratio of a computed distance between two clusters would be considered as the inter-cluster distance and should be maximal for effective routing". The inter-cluster distance was determined using the Eq. (3).

$$Y^* = \left(\frac{\sum_{y=1}^{m} \sum_{k=y+1}^{m} Y(R_{y,} R_k)}{\alpha} \right) \quad (3)$$

Where, $Y(R_{y,} R_k)$ indicates the distance among the two clusters and m denotes the total CH.

3.4 Distance

"The summation of the distance computed among the two hops and it should be minimal for multihop routing". The distance in multihop outing can be expressed in Eq. (4).

$$T = \frac{1}{a} \times \left(\frac{\sum_{t=1}^{a-1} Y(H_{t,} H_{t+1})}{\alpha} \right) \quad (4)$$

3.5 Link Lifetime

"The network lifetime can be derived from the link lifetime and it should be maximal to attain effective routing". The link lifetime can be determined using the Eq. (5).

$$O = \frac{1}{a} \times \frac{\sum_{t=1}^{a-1} O(H_{t,} H_{t+1})}{\alpha} \quad (5)$$

Where, $O(H_{t,} H_{t+1})$ indicates the link lifetime from t^{th} hop and $(t+1)^{th}$ hop.

4. D-MBO: Improved Algorithm for Optimal Routing

4.1 Solution Encoding

The nodes are given as solutions for encoding in the proposed work as represented in Fig.2, where, N_1 be an initial node, N_4 be a target node and the optimal route $N_1 \rightarrow N_2 \rightarrow N_3 \rightarrow N_4$ were chosen by D-MBO algorithm.

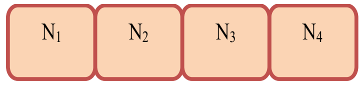

Fig. 1. *Solution Encoding*

4.2 Fitness Function

"The fitness function is calculated using a set of parameters to find the optimal solution from such a solution". For routing, the solution providing energy, delay, inter-cluster distance, distance and link lifetime is chosen. In MRP, the solution that generates optimum fitness value was considered. The fitness of the D-MBO algorithm can be represented using Eq. (6).

$$\begin{aligned} F &= w_1 Q + w_2 \times (1 - D) + w_3 \times (1 - Y^*) + w_4 \times Y \\ &+ w_5 \times (1 - T) + w_6 \times O + w_7 \times L, \end{aligned} \tag{6}$$

Where, D indicates the transmission delay, Y^* represents the inter-cluster distance. "w_1, w_2, w_3, w_4, w_5, w_6 and w_7 denotes the weights computed using the fuzzy membership function". Q indicates the node's energy, T denotes the distance among the 2 hops, "Y be a intra-cluster distance and O be a link-time and the trust model can be determined as L". The weight can be determined in Eq. (7).

$$w = \begin{cases} 0; \text{if}(n < e) \\ \frac{n-e}{l-e}; \text{if}(e \le n \le l) \\ \frac{m-n}{m-l}; \text{if}(l \le n \le m) \\ 0; \text{if}(n \ge e) \end{cases} \tag{7}$$

Where,"l, m and n indicates the vertices of triangular membership function $T(e)$. Here, l be a lower boundary, m indicates medium boundary with membership value 1 and n be an upper boundary with membership value 0".

4.3 D-MBO Algorithm

MBO is ideally suited for parallel processing and is capable of making trade-offs between intensification and diversification. In addition, the MBO algorithm has simple calculation process, requires less computational parameters, and is easy to implement by a program. Monarch butterflies migration process [20] would be used to address several optimization problems for certain features, including (i) Monarch butterflies total distribution is restricted to Land A and Land B. (ii) Every single child monarch butterfly is generated by the migration operator for both regions including such Land A and Land B. (iii) Throughout the MBO approach, as only a new one would be formed, the parent butterfly must leave the pack to retain a stable population in the pack (iv) performance and quality of monarch butterfly is guaranteed through ensuring that the output could not be diminished as the generations expand.

Migration Operator: "P be the total number of the population, and V indicates the ratio of butterflies in Land A and Land B. The Land A and Land B are renamed as subp1 and subp2 ".

$$c_{j,z}^{d+1} = c_{r2,z}^{d} \tag{8}$$

In Eq. (8), the $c_{j,z}^{d+1}$ indicates the migration process species of the z^{th} component of c_j in the monarch butterfly j at generation $d+1$ and $c_{r_1,z}^{d}$ represents the z^{th} component of c_{r_1} in which the novel location in monarch butterfly r_1. Here, the variable d represents the present generation. From subp1, the monarch butterfly r_1 can be selected randomly. In Eq. (8), the component z for the new monarch butterfly was determined at $r \le v$. The r value can be represented using the Eq. (9).

$$r = u * time \tag{9}$$

"Here, the variable ' time 'defines the migration period that are introduced on the basis of 12 months of each year which could be specified as 1.2. The variable u is an arbitrary value chosen from a same distribution. The newly produced monarch butterfly component y is introduced". Where $r > v$, Eq. (10) is formed.

$$c_{j,z}^{d+1} = c_{r2,z}^{d} \tag{10}$$

In Eq. (10), $c_{r_2,z}^{d}$ denotes the z^{th} component of c_{r_2} that is introduced the location for monarch butterfly r_2. The subp2 of monarch butterfly r_2 can be selected randomly. "By regulating the ratio c the stability of the direction of migration operator were examined in the MBO method". The v value represents the subpopulation such as sub1 and subp2 would be selected. The v value can be 5/12 in current estimation.

Butterfly Balancing Operator: "In addition to migration operator the balancing operator is often being used to monitor the monarch butterflies' position. In each component of the monarch butterfly were arbitrarily produced value u will be less than or equivalent to v ". The memory can be reviewed using the Eq. (11).

$$c_{y,z}^{d+1} = c_{best,z}^{d} \tag{11}$$

In Eq. (11), " $c_{y,z}^{d+1}$ indicates the z^{th} component of c_y for the generation $d+1$ that represents the location in monarch butterfly y. However, $c_{best,z}^{d}$ denotes the z^{th} component of c_{best} in which the best monarch butterfly in Land A and Land B. Consequently, the v value is less than u ". The memory can be determined using the Eq. (12).

$$c_{y,z}^{d+1} = c_{r_3,z}^{d} \tag{12}$$

In Eq. (13), $c_{r_3,z}^{d}$ indicates z^{th} component of c_{r_3} that can be randomly selected in Land B. Here, $r_3 \in \{1,2,\ldots,P_2\}$

$$c_{y,z}^{d+1} = c_{y,z}^{d+1} + \varphi \times (f_z - 0.5) \tag{13}$$

When, " $u > h$ the memory can be updated additionally as determined in Eq. (13). Here, h specifies butterfly's balancing value. The variable f indicates the monarch butterfly y walk steps". The Levy flight were represented using the Eq. (14) and (15).

$$f = \text{Levy}(c_y^d) \tag{14}$$

$$\varphi = S_{dim} / d^2 \tag{15}$$

The weighting element φ can be determined using the Eq. (15). Where, " S_{dim} indicates the value at a single move. When the value of φ is high, it indicates the extended space of exploration that maximize the impact of f on $c_{y,z}^{d+1}$ with enhance in identification of more search space. Where, the value of φ is low it identifies the short space of exploration, with minimized impact of f on $c_{y,z}^{d+1}$ in exploitation process".

In particular, MBO algorithm seems to have the ability of solving different standard optimization problems for searching the improved functions. In addition, further to improve the efficiency of traditional MBO, the updated algorithm named D-MBO is proposed here. Improved algorithms helps in solving complex optimization problems which typically have non-convex and highly nonlinear solution spaces, and which are otherwise computationally difficult to solve by conventional mathematical programming methods. The MBO algorithm process can be divided into 2 major processes such as "migration operator and butterfly adjusting operator". However in conventional MBO, it is splitted into two sub population arbitrarily. As an alternative," the proposed D-MBO algorithm divide the sub population depending on the distance function in which the distance among the best solution and the current solution" as shown in Eq. (16). Here " c_{best} and c_y indicates the best solution and current solution", correspondingly.

$$\text{Dis} = c_{best} - c_y \tag{16}$$

The solution of minimum distance can be sorted as 1st half set would be calculated as subp 1 and second half is measured as subp 2. Consequently, "the final best solution would be an effective with better convergence".

5. Results and Discussion

5.1 Simulation Procedure

The proposed routing protocol for WSN was analysed using MATLAB and their resultants can be obtained. The D-MBO model was compared with other traditional methods such as PSO [16], GWO [18], FF [17] and WOA [19] and the results were attained. The experimental outcomes were observed for such measures like energy, delay, throughput and alive nodes and their results were confirmed.

5.2 Analysis on Energy and Delay

The analysis on energy for the D-MBO method was compared with the conventional models as shown in Table 1. Here, the analysis of energy was attained by D-MBO method over the traditional schemes for different number of rounds such as 500, 1000, 1500 and 2000. The proposed D-MBO method is superior to other traditional algorithms such as PSO, GWO, FF and WOA for all four numbers of rounds.

The analysis for delay in D-MBO method was conventional models can be demonstrated in Table 2. The analysis of network lifetime obtained using the D-MBO method compared to conventional models based on different rounds such as 500, 1000, 1500 and 2000 nodes. The D-MBO model obtains the value of 0.27 which is better than other existing algorithms such as GA, FF and DA in 2000th rounds. Thus, the betterment of the D-MBO method achieved betterment in the results.

Table 1. *Analysis On Energy For D-MBO Method Over Conventional Models*

Methods	Number of rounds			
	500	1000	1500	2000
D-MBO	0.45	0.3	0.21	0.13
PSO [16]	0.44	0.23	0.15	0.06
GWO [18]	0.21	0.14	0.09	0.05
FF [17]	0.35	0.18	0.10	0.05
WAO [19]	0.30	0.1	0.04	0.02

Table 2. *Analysis on delay for D-MBO method over conventional models*

Methods	Number of rounds			
	500	1000	1500	2000
D-MBO	0.2	0.25	0.27	0.27
PSO [16]	0.25	0.28	0.28	0.28
GWO [18]	0.48	0.49	0.5	0.5
FF [17]	0.41	0.47	0.48	0.48
WAO [19]	0.41	0.45	0.46	0.46

5.3 Analysis on Throughput and Alive Nodes

Table 3 demonstrates the throughput in D-MBO method compared to other traditional models. The D-MBO algorithm provides better outcomes than the other compared models for the different number of rounds.

Table 4 represents the alive nodes present in the D-MBO method over other traditional schemes. Here, the D-MBO algorithm obtains higher values than the other compared models in all rounds such as 500, 1000, 1500 and 2000. At 2000th round, the D-MBO method is superior to the traditional models such as PSO, GWO, FF and WAO, respectively.

Table 3. *Analysis on throughput for D-MBO method over conventional models*

Methods	Number of rounds			
	500	1000	1500	2000
D-MBO	1	1	0.9	0.1
PSO [16]	1	1	0.87	0.3
GWO [18]	1	1	0.86	0.2
FF [17]	1	1	0.88	0.1
WAO [19]	1	1	0.87	0.2

Table 4. *Analysis on alive nodes for D-MBO method over conventional models*

Methods	Number of rounds			
	500	**1000**	**1500**	**2000**
D-MBO	50	40	33	26
PSO [16]	48	35	32	25
GWO [18]	40	30	28	21
FF [17]	47	25	20	14
WAO [19]	45	28	15	5

5.4 Overall Performance Comparison

The overall analysis of performance comparison in D-MBO method for 50th and 100th nodes can be demonstrated in Table 5, from which the betterment of the D-MBO method can be observed. Here, for 50th and 100th number of rounds there is betterment in the D-MBO method over the other traditional methods like PSO, GWO, FF and GAO.

Table 5. *Overall Performance Comparision of D-MBO method over conventional models*

Methods	Energy		Delay		Throughput		Alive nodes	
	nodes		nodes		nodes		nodes	
	50	100	50	100	50	100	50	100
D-MBO	0.188	0.129	0.291	0.465	0.1	0.1	25	42
PSO [16]	0.052	0.065	0.481	0.687	0.1	0.1	5	25
GWO [18]	0.108	0.003	0.501	0.889	0.1	0.1	13	12
FF [17]	0.142	0	0.524	0.621	0.1	0.1	21	0
WAO [19]	0.152	0.119	0.316	0.485	0.1	0.1	24	39

6. Conclusion

This work introduced the D-MBO method for identifying the optimal routing in WSN. In this work, the optimal routing path was chosen using D-MBO method by considering the factors like “energy, delay, intercluster distance, link lifetime and distance”. The D-MBO method provided better performance than the traditional methods such as throughput, delay, energy and distance. From the analysis, the D-MBO model obtains the value of 0.27 which was better than other existing algorithms such as GA, FF and DA in 2000th rounds for delay measures. Finally at 2000th round, the D-MBO method is superior to the traditional models such as PSO, GWO, FF and WAO, respectively for distance measures. Thus, the enhancment of the presented scheme was validated in an effective manner.

Compliance with Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

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