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Artificial Neural Network based Optimized Link State Routing Protocol in MANET

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Abstract: Mobile Ad hoc Network (MANET) includes many wireless mobile nodes, and higher energy consumption is the major concern in MANET. Compared to other protocols, the Optimized Link State Routing Protocol (OLSR) is a superior pro-active protocol, which works on limited configuration attribute variables in the MANET. In a dynamic environment, default variables of the attribute are not suitable as per the IETF draft. Therefore, the Artificial Neural Network (ANN) is integrated with the OLSR protocol in this manuscript. In addition, the OPNET modeler is used to evaluate the performance of ANN based OLSR protocol, which is simulated by utilizing the MATLAB software environment. The performance measures such as Routing Overhead Ratio (ROR), End to End Delay (EED), Energy Consumption (EC), and Packet Delivery Ratio (PDR) are employed for analysing the protocol's performance. The simulation result revealed that the ANN based OLSR protocol effectively increases the network lifespan and reduces EC of the MANET network. Compared to the Ant Colony Optimization (ACO) based Modified Ad-hoc On Demand Distance Vector (MAODV) and Prevention of Selfish Node using Hash Function (PSNHF) based AODV protocols, the proposed ANN based OLSR protocol achieved higher PDR of 99.92%, 99.90%, and 99.89% on the nodes of 80, 90 and 100.

Keywords: Ad hoc network, Artificial neural network, Deep learning techniques, Energy consumption, OLSR protocol.

1. Introduction

In recent times, the MANET technology comprises a group of multiple wireless devices like a personal device or a laptop [1, 2]. MANET technology aims to set the multiple wireless devices in an effective manner, where the nodes are capable to connect beyond their transmission range by cooperatively transferring the data packets to each-other. These networks are independent of centralized administration, access points, and base stations [3]. In the ad-hoc network function, the node and the router act simultaneously. In the multi-nodal process, a few nodes act as hosts and other nodes act as intermediate nodes, which transmits the data packets from the source host to the final destination. [4, 5]. The architecture is flexible and can adapt and adjust with time by changing its parameters that is a challenging process to develop routing protocols for the systems, which are flexible, changing dynamically, and the nodes move arbitrarily and frequently [6]. Similarly, the node route is also changed that increases the chance of packet dropping. If a fault occurs, it is hard to check, because every node acts as an independent unit and creates the data independently [7, 8]. So, the network management has to be distributed across all nodes. Additionally, each node operates at a different frequency band with one or more radio interfaces causing symmetric links.

The difference in hardware and software configurations might impart different processing capabilities. The successful working of such systems needs efficient scalability and the steps involved in the system are proper routing, addressing, security, location management, interoperability, configuration management and high capacity wireless technologies [9, 10]. These concerns are solved by setting proper routes. The routing protocols need to construct an effective route for sending a data packet to reduce the packet loss and EC, which are considered the most fundamental problems in the MANET. The OLSR protocol significantly classifies the qualitative and quantitative properties, where the qualitative properties include “distributed operation, loop freedom, unidirectional link support, security, and demand-based operation”. The OLSR is the trivial protocol, which provides the link-state information in the MANET [11, 12]. In this manuscript, the soft computing model named ANN is used to improve the security of the MANET. The metrics like ROR, EED, PDR, and EC are utilized for analyzing the proposed ANN based OLSR protocol’s performance.

This manuscript is organized as follows: a few articles related to this study are reviewed in Section 2. The theoretical explanation, experimental analysis, and the conclusion of the ANN based OLSR protocol are given in Sections 3, 4, and 5.

2. Related works

Vikkurty and Pallam Shetty [13] evaluated the effectiveness of the fuzzy logic based OLSR protocol in MANET for different network sizes. The extensive experiment confirmed that the presented protocol performed effectively in the large, medium, and small networks related to the conventional protocols. The presented protocol nearly increased five times of throughput related to prior protocols. Additionally, the presented protocol design needs to be secure and energy efficient in MANET. Kanagasundaram and Ayyaswamy [14] implemented an energy-efficient and secured OLSR protocol on the basis of multi-objective Ant Lion Optimizer (ALO) in the MANET environment. The experimental results showed that the presented OLSR protocol with a multi-objective ALO algorithm outperformed the prior protocols by means of EC, network lifetime, delay and throughput. As stated in the future work, the presented OLSR protocol with multi-objective ALO algorithm needs to be concentrated on both attack of collusion and attack of node capture.

Zhang, [15] implemented a novel quantum genetic based OLSR protocol in the MANET. In this literature study, the augmented Q learning method effectively optimizes the multi-point relay set, which improves the data packet delivery rate and decreases the time delay of packet transmission and network power consumption. Experimental valuation showed that the presented quantum genetic based OLSR protocol was efficient and reliable related to other protocols. However, the quantum genetic based OLSR protocol suffered from several concerns like overhead, EED, and difficulty in handling the void zones. Jubair, [16] has included the bat algorithm in the OLSR protocol for improving the energy usage in MANET. In the resulting phase, the presented OLSR protocol efficiency was validated by means of EC, overhead ratios, and EED. The experimental results revealed that the presented bat optimized OLSR protocol effectively decreases the network EC, and increases the network lifespan compared to the existing protocols. Due to irregular node movement, the presented bat optimized OLSR protocol faced a high overhead ratio.

In addition, Hamzaoui, [17] improved the OLSR protocol efficiency in MANET by integrating the k-means clustering algorithm. As denoted in the future extension, the over-head ratio was high, while using the k-means clustering algorithm in MANET. Fardin Far and Alaei [18] introduced a new model based on the genetic algorithm and OLSR protocol for reducing EC in the MANET. In this study, the multi-point relay was upgraded in the OLSR protocol using a genetic algorithm. The experimental analysis showed that the developed OLSR protocol obtained superior performance than the conventional OLSR by means of network lifetime and operating power. Still, the developed OLSR protocol needs to concentrate on EC, which was a major concern in the MANET.

Anantapur and Patil, [19] implemented an ACO based MAODV for attaining secure transmission over MANET. In this literature, the ACO algorithm considers node degree, trust, distance and residual energy as fitness functions for detecting the optimum path under the constraints of black-hole attacks. The metaheuristic optimization algorithm: ACO faced difficulty in handling the void zones. Anantapur and Patil, [20] introduced a new PSNHF based AODV protocol to minimize packet loss through the MANET network. In this literature, the presented AODV-PSNHF protocols performance was analysed by means of EC, PDR, and throughput. As a future extension, incentive techniques can be added for motivating the selfish nodes to become normal nodes. For highlighting the above mentioned concerns, the deep learning model named ANN is integrated with the OLSR protocol.

3. Methodology

The ad-hoc network is a wireless network, which shares information using multi-hop links. The ad-hoc network is infrastructure-free and has no stationary base station for communication. To receive and

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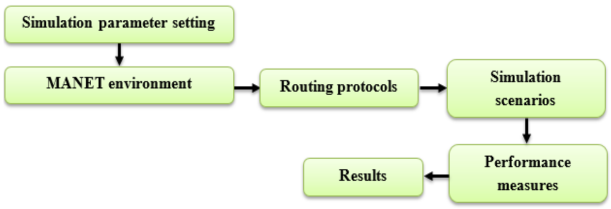

Figure. 1 Architecture of the MANET environment

transmit the packets from one node to another node, a networking device: a router is used [21, 22]. The implementation of wireless routing networks in the ad network is a challenging mechanism, because no fixed topology is available, due to the higher mobility of nodes, which is considered a major concern in the wireless network [23].

The MANET uses many protocols for transmitting the data packets among nodes. Several protocols are proposed and their utilization completely relies upon the application and network design. This study aims to develop a pro-longed lifetime network with an efficient protocol with limited power consumption to avoid delays in relaying events. Apart from the EC, the MANET ensures scalability for decreasing node failure [24]. The neural network is extensively used for enhancing the network and node lifetime, so, the OLSR protocol based on ANN is introduced in this article. The architecture of the MANET environment is graphically specified in Fig. 1.

The ANN processes the information based on the structure and function, which is inspired by the human brain. The neural network comprises several organized neurons, where each neuron processes the information. Each neuron receives many signals from various input links and the neurons are associated with weight function. The structure of the neural network depends on the learning algorithm utilized by the neurons. The learning algorithm deals with adjusting weights and threshold values until the criterion is met. The learning techniques are generally classified as reinforcement, unsupervised and supervised. The ANN has an efficient learning ability to forecast things. Therefore, the ANN model is integrated with the OLSR protocol for determining its applicability for other network sizes. Generally, the ANN is divided into three sorts of parameters such as activation functions, which transforms the neuron's weighted input into its output activations, inter-connection design between several layers of neurons, and learning process used for updating the weights between inter-connection. During the design mechanism, several variables need to be created. Fig. 2 and 3 denote the creation of input variables and output variables during the design of the network.

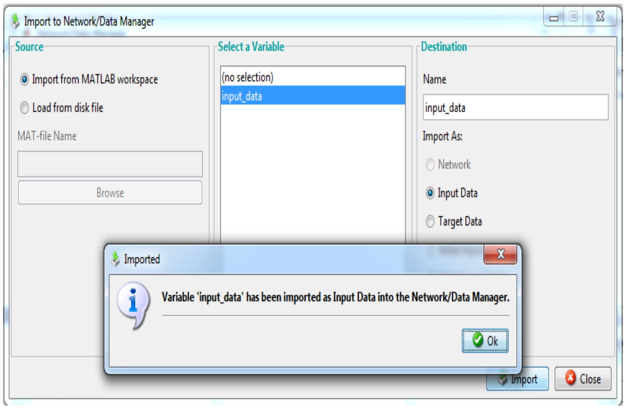

Figure. 2 Creation of input variable for the input data

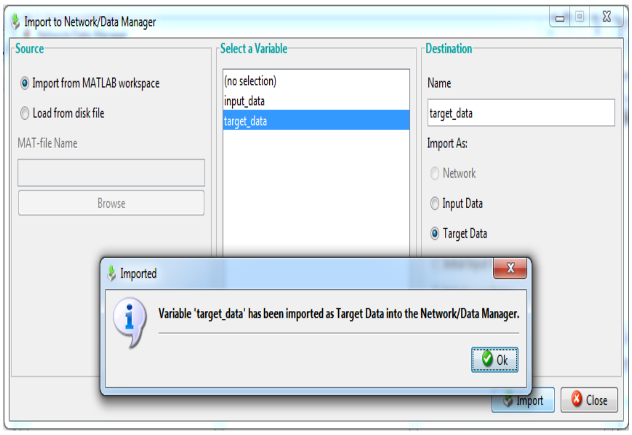

Figure. 3 Creation of target variable for the target data

The back propagation concept is used as part of the feed forward ANN model, where "feed forward" states the recall pattern of the neural network and the term "back propagation" states the repetitive learning process of the neural network. In the ANN, the network obtains input from the neurons in the input layer and then the network output is fed to the neurons in the output layer, where the ANN model includes one or more intermediate hidden layers. Hence, the ANN model's architecture is indicated in Fig. 4 that includes three main layers: input, hidden, and output layers.

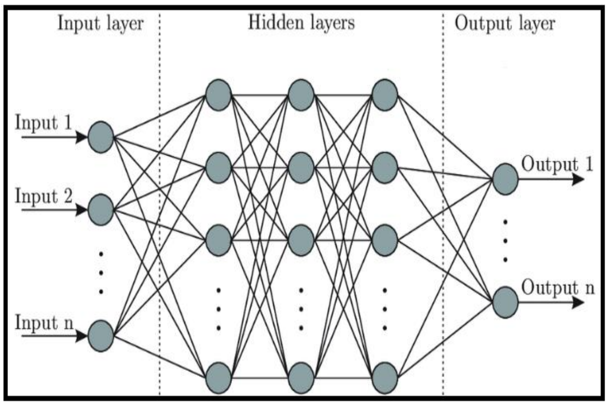

Figure. 4 Architecture of the ANN model

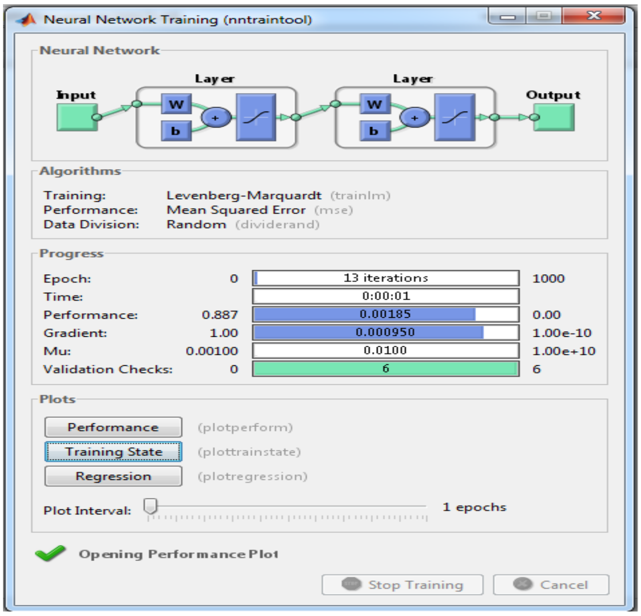

Figure. 5 Graphical presentation of the neural network training

The input and the output layers consist of several nodes, which corresponds to the input and the output values. The input data moves between the layers across the weighted connections. The node accepts the data from the previous layers, and then calculates a weighted sum of the input t, as denoted in Eq. (1).

$$t_i = \sum_{j=1}^{n} W_{ij} X_j \quad (1)$$

Where, X represents input data from node j, W states interconnection weight between nodes i and j and n states number of inputs. In the ANN model, the transfer function is employed in the weighted value t for analysing the node output value O_i . The frequently utilized transfer function in the ANN model is sigmoidal function, which is applied in both output and hidden layers [25]. In this study, the linear transfer function is utilized in the input layer that is defined in Eq. (2).

$$O_i = f(t_i) \quad (2)$$

Eq. (2) holds only true value for the neurons with linear activation function, so the non-linear activation function is employed in this study, which is mathematically defined in the Eqs. (3) and (4). Lastly, the error sub-ordinate is determined using chain rule based on the weight value [26, 27].

$$t_i = \emptyset(net) \quad (3)$$

Where,

$$net = \sum_{j=1}^{n} W_{ij} X_j \quad (4)$$

$$\frac{\partial E}{\partial W_{ij}} = \frac{dE}{dt_i} \times \frac{dt_i}{d_{net}} \times \frac{d_{net}}{\partial W_{ij}} \quad (5)$$

Where, $\frac{d_{net}}{\partial W_{ij}}$ states weighted sum change, $\frac{dt_i}{d_{net}}$ states output change is directly proportional to the weighted sum change, $\frac{\partial E}{\partial W_{ij}}$ represents error change is directly proportional to the weights change and $\frac{dE}{dt_i}$ denotes error change, which is directly proportional to the output change. The neural network training is graphically specified in Fig. 5. The parameter setting of the ANN is given as follows: error is 0.001, momentum rate is 0.4, learning rate is 0.01, iteration is 50, and the number of neurons in the hidden, output and input layers are 40, 2, and 94.

4. Experimental results

In this manuscript, the ANN based OLSR protocol effectiveness is validated in a MANET simulation environment by using MATLAB 2020a software tool on a system configuration with 16 GB random access memory, 4TB hard-disk, Intel core i9 processor, and windows 10 operating system. Initially, the MANET is used for creating the simulation environments and it integrates bandwidth, number of nodes, network size, etc. Secondly, the MATLAB computer programming software is used to implement several algorithms with mathematical equations such as ANN. Additionally, the MATLAB software tool requires functions and iterations to facilitate the implementation process, where the simulation snapshot is graphically mentioned in Fig. 6. Thirdly, the routing protocol efficiency is tested in light of EC, ROR, PDR and EED in order to assess the performance quality of the protocols.

In this manuscript, the proposed ANN based OLSR protocol's effectiveness is validated by means of EC, ROR, PDR, and EED. In addition, the ANN based OLSR protocol performance is analysed by comparing its results with the existing protocols like AODV, Dynamic Source Routing (DSR), Zone Routing Protocol (ZRP), Destination Sequenced Distance Vector (DSDV), OLSR, Fuzzy Logic based OLSR [13], OLSR with multi-objective ALO algorithm [14], OLSR with bat algorithm [16], MAODV-ACO [19], and PSNHF based AODV protocol [20]. The performance is analysed by varying the node size such as 40, 50, 60, 70, 80, 90, and 100. In addition, the simulation parameter setting is depicted in Table 1.

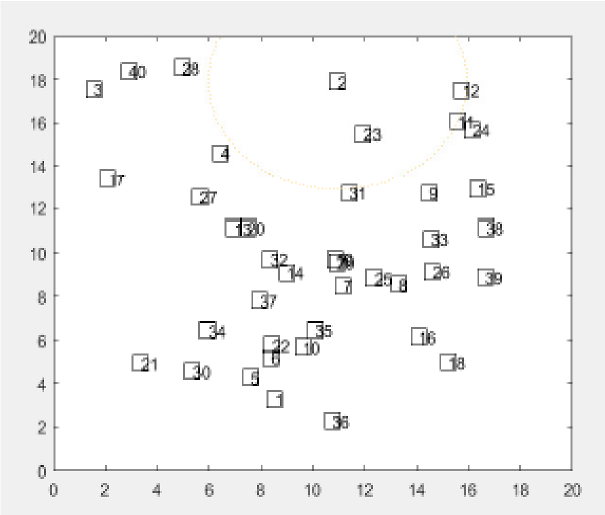

Figure. 6 Simulation snapshot

Table 1. Simulation parameter setting

Routing Protocols / Approaches	OLSR with ANN
Nodes	94
Nodes Placement model	Random
Mobility Model	Random Waypoint
Node Transmission Power	0.005mw
Operational mode	802.11b
Data rate	11Mbps
Simulation Time	300 seconds
Area (sq. m)	1000 * 1000
Traffic	Exponential
Speed	18 m/s

The OLSR protocol avoids EC between the intermediate nodes on the path of data transmission, and ANN is employed for estimating the network condition by detecting the inter-arrival time of the data packets. Hence, the ANN based OLSR protocol performance is measured by using numerous performance metrics like EC, ROR, PDR, and EED. The EED denotes accumulative time, which is consumed to transfer the data packets across the MANET network. The EED is mathematically denoted in Eq. (6).

$$End\ to\ end\ delay = \frac{\sum_{i=1}^{n}(Ri-Si)}{n} \quad (6)$$

Where, n specifies successful data packets, which are received by destination node, Si states packet sending time, Ri denotes packet receiving time, and i denotes unique packet identifier. Then, the ROR is defined as the ratio of the total number of routing packets and successfully delivered data packets, which is mathematically specified in Eq. (7).

$$ROR = (\sum \frac{Routing\ packets}{Routing\ packets + Delivered\ data\ packets}) \times 100 \quad (7)$$

In addition, the EC is defined as the energy consumed by the nodes with-in the MANET network, during simulation time. After simulation, the consumption of energy is computed utilizing the energy level of each node. The EC is mathematically specified in Eq. (8).

$$Energy\ consumption = \sum_{i=1}^{n} ini(i) - ene(i) \quad (8)$$

Where, n indicates number of nodes, i specifies counter, ene states energy level of the nodes, and ini represents initial energy level of the nodes. Further, the PDR is defined as the ratio between the amount generated packets to the amount of received packets, and it is mathematically depicted in Eq. (9).

$$PDR = \frac{\sum_{0}^{n} packets\ received}{\sum_{0}^{n} packets\ sent} \times 100 \quad (9)$$

Where, n represents number of nodes.

4.1 Quantitative analysis

In this section, the proposed ANN based OLSR protocol's performance is validated in terms of EED. The obtained results are compared with conventional protocols like AODV, DSR, DSDV, OLSR, ZRP, fuzzy logic based OLSR [13], OLSR with multi-objective ALO [14] and OLSR with bat algorithm [16] by varying the node size like 40, 50, 60, 70, 80, 90, and 100. By inspecting Table 2, the proposed ANN based OLSR protocol almost reduced 3 to 4 times of EED compared to the existing routing protocols in MANET.

Fig. 7 represents the graphical comparison of the protocol results in terms of EED by varying the number of nodes. The OLSR protocol has a high EED, so ANN is included in this manuscript to select the optimal multi-point relay (route). Generally, the average delay is constant for lower data rates over the same scenarios, but it increases for higher data rates, due to the congestion in the network. Related to the existing protocols like ZRP, AODV, DSR, DSDV, OLSR, fuzzy logic based OLSR [13], OLSR with multi-objective ALO [14] and OLSR with bat algorithm [16], the ANN based OLSR protocol has achieved a superior result by means of EED.

Table 2. Experimental results of ANN based OLSR in terms of EED

EED (seconds) (mean value)							
Protocols	Number of nodes						
	40	50	60	70	80	90	100
AODV	92	108	129	140	155	167	180
DSR	82	99	112	122	130	155	164
DSDV	80	91	100	102	128	149	148
OLSR	63	85	82	88	122	138	143
ZRP	44	62	72	82	114	134	129
Fuzzy Logic based OLSR [13]	41	45	70	73	105	112	122
OLSR with multi-objective ALO [14]	32	40	60	68	98	96	102
OLSR with bat algorithm [16]	20	32	45	60	79	86	97
ANN based OLSR	15	26	38	47	70	77	82

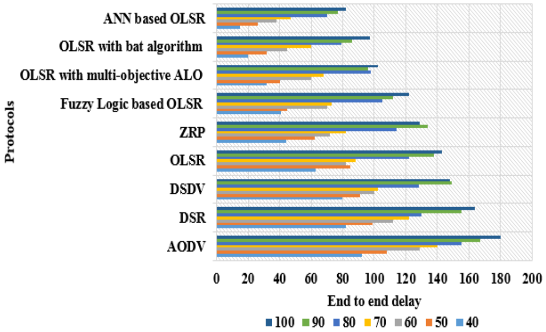

Figure. 7 Graphical comparison of the protocols results by means of EED

Table 3 represents the EC performance of different protocols. Compared to the existing protocols such as AODV, DSR, DSDV, OLSR, ZRP, fuzzy logic based OLSR [13], OLSR with multi-objective ALO [14] and OLSR with bat algorithm [16], the developed ANN based OLSR protocol obtained limited EC. Due to the low number of hops, higher throughput is achieved by the developed protocol. The graphical comparison of the protocols results by means of EC is depicted in Fig. 8.

Table 3. Experimental results of ANN based OLSR in terms of EC

EC (Joule) (Mean value)							
Protocols	Number of nodes						
	40	50	60	70	80	90	100
AODV	55.55	65.58	69.28	72.09	80.90	90.93	122.02
DSR	48.78	52.70	58	60.70	79.78	88.30	109.92
DSDV	43.39	49.38	55.30	58.38	73.30	83.30	102.12
OLSR	40.23	48.20	49.20	54.20	68.20	80.93	100.04
ZRP	40.11	44.12	47.17	53.50	65.10	77.13	98.92
Fuzzy Logic based OLSR [13]	39.83	42.88	44.80	53.34	64.82	72.87	96.65
OLSR with multi-objective ALO [14]	38.56	39.99	44.59	51.38	60.43	69.93	95.84
OLSR with bat algorithm [16]	32.83	36.67	42.37	50.98	57.92	65.92	92.98
ANN based OLSR	28.12	30.80	38.90	49.80	52.20	61.02	88.23

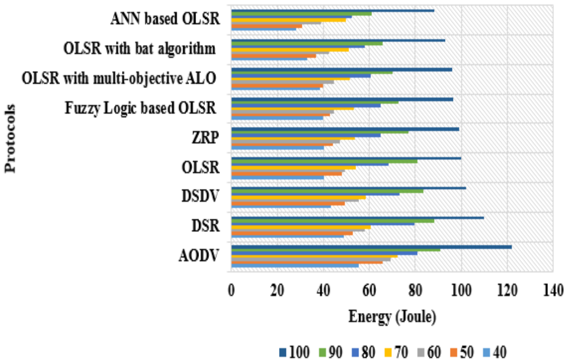

Figure. 8 Graphical comparison of the results of the protocol by means of EC

Table 4 represents the ROR performance of the existing and proposed protocol. The ROR is analyzed by the number of information packets, which are effectively got at the destination node. Table 4 demonstrated that the execution of the proposed protocol is more effective than the related protocols. Whereas, the estimation of ROR is faster in the proposed protocol, since it sends the quantity of information related to AODV, DSR, DSDV, OLSR, ZRP, fuzzy logic based OLSR [13], OLSR with multi-objective ALO [14] and OLSR with bat algorithm [16]. The graphical comparison of the protocols results by means of ROR is depicted in Fig. 9.

Table 4. Experimental results of ANN based OLSR in terms of ROR

ROR (%) (Mean value)							
Protocols	Number of nodes						
	40	50	60	70	80	90	100
AODV	26.78	28.92	34.44	36.90	40.90	43.92	45.32
DSR	25.29	27.20	33.33	35.20	38.70	40.22	42.01
DSDV	23.70	25.30	30.93	32.01	34.40	35.45	42.20
OLSR	20.45	21.59	24.50	26.36	28.47	29.65	31.52
ZRP	16.35	16.96	20.14	20.23	21.02	22.44	25.18
Fuzzy Logic based OLSR [13]	13.65	14.96	16.09	18.33	19.23	19.11	22.11
OLSR with multi-objective ALO [14]	12.16	13.43	14.82	15.01	16.19	16.88	17.54
OLSR with bat algorithm [16]	10.29	12.34	13.20	14.92	15.27	16.02	17.29
ANN based OLSR	9.42	10.92	11.12	13.20	14.24	15.45	16.55

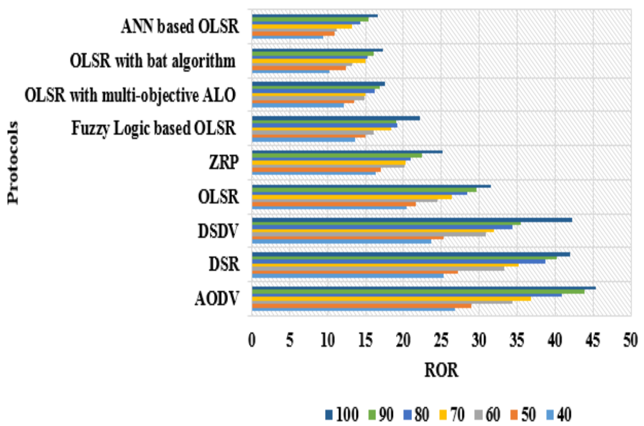

Figure. 9 Graphical comparison of the protocols results in light of ROR

Table 5. Experimental results of ANN based OLSR in terms of PDR

PDR (%)			
Protocols	Number of nodes		
	80	90	100
AODV	76.84	77.40	78.50
DSR	82.30	84.30	80
DSDV	84.60	88.50	89.06
OLSR	94.90	92.85	90.94
ZRP	96.70	96.50	97.77
MAODV-ACO [19]	99.48	99.87	99.66
PSNHF based AODV [20]	90	82	89
ANN based OLSR	99.92	99.90	99.89

Table 5 represents the PDR performance of different protocols. Related to the comparative protocols such as AODV, DSR, DSDV, OLSR, ZRP, MAODV-ACO [19] and PSNHF based AODV protocols [20], the developed ANN based OLSR protocol obtained high PDR of 99.92%, 99.90%, and 99.89% on the number of nodes of 80, 90 and 100. Especially, this experiment is performed on a parameter specification with initial energy of 2 Joule, packet size of 512 bytes, propagation model of two ray ground, network interface type of phy/wireless phy, antenna model of omnidirectional, area of $300 \times 300m^2$ and $500 \times 500m^2$ and maximum mobility speed of $10\ m/s$.

5. Conclusion

In recent decades, it is necessary to develop techniques for adjusting the configuration attributes in the OLSR to improve MANET's performance. The deep learning models have a superior learning ability to forecast things. Therefore, the ANN is integrated with the OLSR protocol to check its suitability for various network sizes. The simulation result revealed that the ANN based OLSR protocol significantly decreases the EC and increases the lifespan of MANET. As represented in the resulting phase, the ANN based OLSR protocol diminishes EED, EC, and ROR, which are three to four times better compared to the existing protocols: AODV, DSR, ZRP, DSDV, OLSR, fuzzy logic based OLSR, OLSR with multi-objective ALO, and OLSR with bat. Further, the ANN based OLSR protocol achieved maximum PDR of 99.92%, 99.90%, and 99.89% on the nodes of 80, 90 and 100, and it is better compared to the MAODV-ACO and PSNHF based AODV protocols. As a future extension, a new hybrid optimization algorithm is combined with OLSR protocol to further increase the lifespan and reduce the EC of MANET.

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Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

The paper background work, conceptualization, methodology, dataset collection, implementation, result analysis and comparison, preparing and editing draft, visualization have been done by first author. The supervision, review of work and project administration, have been done by second author.

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