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Energy-Aware Multipath Routing Scheme Based on Particle Swarm Optimization (EMPSO)

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Abstract – *Every node in an ad hoc network are constrained by energy power for their operation. Communication (transmission and reception) is one of the main sources of energy consumption in Mobile Ad hoc Networks. Since the rate of battery performance improvement is rather slow and in the absence of breakthroughs in this field, other measures have to be taken to achieve the goal of getting more performance out of the currently available battery resources. In this work, the main focus is to develop a method of energy in communications between ad-hoc network nodes. This proposed model which selects best path by considering energy parameter. a particle swarm optimization (PSO) is used for optimized route selection.*

Key Words: **Energy, PSO, Optimization, MAODV, Battery.**

1. INTRODUCTION

MANET consists of mobile nodes with limited energy and wireless link. Each mobile node forwards the packets from source to destination. MANET is represented as directed graph $G = (V, E)$. The vertices V ∈ V are a symbol of the mobile nodes and the neighbor node. An edge $(u,V) \in E$is a symbol of a wireless link between nodes u,V, which forward packets to others. The energy consumption for forwarding packets from a node u to node V is given by:

$$E_{tx}(k,d) = E_{elec}(K) + E_{amp}(k,d) \text{ ....(1.1)}$$

where k is number bits and d is the distance between nodes. E_{elec}, E_{amp} are energy dissipated per bit to forward and receive packets, respectively. Energy consumption for receiver is calculated by:

$$E_{tx}(k) = E_{elec}(K) \text{ ....(1.2)}$$

The EMPSO routing scheme is composed of three phases: (i) route setup phase, (ii) route discovery phase, and (iii) route maintenance phase. In the route setup phase, each node acquires its metadata of the neighborhood. This metadata is used in the route discovery to find the best next-hop node towards the destination node. The route discovery is activated whenever a source wants to transmit data to destination in an on-demand fashion that prevents multiple interference between source and destination. The route maintenance phase handles path failures during data transmission.

1.1 Route Setup Phase

In the route setup phase, source node initiates a data transmission for forwarding packets to the destination. Each node in a MANET obtains its metadata of the neighborhood, which also includes the transmission cost (tc) of its neighbors towards the destination node. The tc value of a link indicates the required number of transmissions for a successful packet reception at the receiver. The transmission cost of a link is given as follows:

$$tc = \frac{1}{p \times q}, \text{ ....(1.3)}$$

where p and q are the probabilities of forward and backward packet reception over a link, respectively. In the initialization phase, each node broadcasts the control packets and stores the number of successfully received packets from its neighbors in the routing neighbourhood table. Then, the destination node sets its transmission cost to zero and broadcasts this value to its neighbors, when a node receives a transmission cost included in a packet.

The algorithm for this phase is as given below.

Algorithm 1: To Setup Route
Input: Control Packets (CP)
Initialize: $\boldsymbol{T_c}$=0;
Broadcast Control Packets;
If received by neighbours
Then
Store in Routing Neighbourhood Table (N-Table)
Calculate Transmission Cost $\boldsymbol{T_c} = \frac{1}{p \times q}$
Else if node is destination
Then
Set $\boldsymbol{T_c}$=0;
Broadcast it to Neighbours.
End if
Else
Find Neighbours
End if

1.2 Route Discovery Phase

Whenever a source node wants to transmit data to destination, the route discovery phase is initiated to find multiple paths from the source to destination. The proposed multipath routing protocol uses reliability measures such as transmission cost, optimal traffic ratio, and remaining energy. The source node starts the route discovery by transmitting a route request packet (RR) towards the destination node. Whenever an intermediate node receives a RR packet, it computes the transmission cost, optimal traffic ratio, and remaining energy for a path that is established between the source and the destination. Then, it also used a found path to forward the RR packet to the neighboring node with minimum cost. There liability measures are stored in the routing table of a node in MANET. The EMPSO scheme uses a continuous time recurrent neural network to find an optimal path among multiple paths. CTRNNs are more computationally efficient in order to use a system of ordinary differential equations to model. The three weight factors such as transmission cost, energy factor, and optimal traffic ratio are taken into the account in CTRNN to find an optimal path. The weight factor of transmission cost is given in

Weight factor for Transmission Cost (T_c)

$$W_{tc} = CR_{pkt}\left(t_{i,j}\right) + DR_{pkt}\left(t_{i,j}\right) \quad \text{.............(1.4)}$$

Where CR_{pkt} is the ratio of transmitted control packets and number of packet transmitted over the network whereas DR_{pkt} is the ratio of transmitted data packets and total number of packet transmitted over the network.

Weight factor for Optimal Path Ratio (OPR)

$$W_{opr} = \frac{1}{p_k \sum_{f=1}^{m} \frac{1}{p_f}} \quad \text{..............(1.5)}$$

Weight factor for Remaining Energy (RE)

$$W_{RE} = E_T - (E_{TX} + E_{RX} + E_{ideal}) \quad \text{.............(1.6)}$$

The algorithm for this phase is as given:

Algorithm 2: To Process and Update RREQs

Input: RREQ Packet
Initialize: T_c =0, OPR=0, RE=0.
For each Neighbour when received a RREQ Packet
If Neighbour is intermediate node then
    Calculate Reliability Measures that is Tc, OPR, RE
    Store in RT (Routing Tables)
    CTRNN is used for weight factor calculation using equations (4.4), (4.5) and (4.6) for Tc, OPR and RE respectively.
    Forward RREQ packet to the Next Hop
Else if Neighbour is destination node.
    Then selection is on the basis of calculated weight factors.
    send RREP to the source node S
End of if
End of if
End of for

1.3. PSO Algorithm

Initially, multiple paths are found by route discovery phase. Then, reliability measures for a path are calculated with help of CRRNN. An optimization technique called PSO is used to find better link quality in a path. PSO can be applied to optimization problems that are partially in dynamic topology changing environment. PSO is an evolutionary optimization technique that may be used to seek a good set of weights in CTRNN. PSO is applied to find the best nodes (particles) involved in a path. PSO is metaheuristic that searches large spaces of candidate solutions. A route with a better link quality is selected for forwarding data from source to destination. If a better link quality is not found, PSO function is performed again until global best solution has been found. PSO reduces the traffic and routing overhead of the optimization process and finds the node with best link quality in an ad hoc network.

The algorithm for this phase is as given:

Algorithm 3: To Process RREP

Input: RREP Packet
Initialize:
For each selected path when received a RREP Packet
If Neighbour is intermediate node then
    Forward RREP packet to the Next Hop
Else if Neighbour is Source node.
    Then PSO is used to select best path.
End of if
End of if
End of for

2. SIMULATION ANALYSIS

In this work, two protocols AOMDV and EMPSO are implemented using NS-2 simulator. EMPSO is energy aware multipath protocol where Particle Swarm optimization is used to select best path for data transmission. These protocols are simulated in the area 1000x1000 m^2. Implementation is done using different scenarios to test the performance of the protocols. The scenarios implemented for testing are as given below:

2.1.1 Scenario1: Varying Nodes

To test the performance of the protocols 50, 100, 150 and 200 nodes are deployed in the area of 1000x1000 m^2 with maximum speed of 50m/s. Simulation is carried out using CBR traffic with maximum 40 connections. Other parameters are as given in the table 2.1.

Table 2.1: Simulation Setup

Simulation Parameters	Values
Area	1000x1000
No. of nodes	50,100,150,200
Speed	0~50m/s
Traffic	CBR
Packet Size	1000 bytes
Packet Rate	250k/s
Pause Time	500s
Simulation Time	1000s
Max Connection	40
Routing Protocol	AOMDV & EMPSO

Results Parameters:

a. Packet Delivery Ratio: This energy based protocol (EMPSO) performs better than AOMDV and achieves 69% improvement in Packet Delivery Ratio. The comparison of these protocols by varying nodes is as given in table 4.2.

Table 2.2: Packet Delivery Ratio

	PDR			
	50	100	150	200
AOMDV	23.0701	23.508	34.3308	33.9252
EMPSO	89.321	93.3463	94.0546	94.658

Figure 1.1 shows the performance of both protocols. This figure also shows that PDR increases with the increase number of nodes and more than AOMDV.

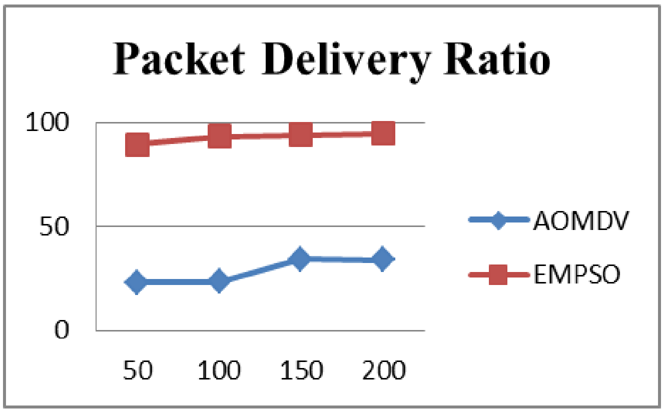

Figure 1.1: Packet Delivery Ratio (Scenario-1)

b. Overhead: This energy based protocol (EMPSO) performs better than AOMDV and achieves 55% improvement in Overhead. The comparison of these protocols by varying nodes is as given in table 1.3.

Table 1.3: Overhead

	Overhead			
	50	100	150	200
AOMDV	15.431	32.664	26.28	26.407
EMPSO	6.038	11.739	13.279	14.092

Figure 1.2 shows the performance of both protocols. This figure shows that Overhead increases with the increase number of nodes but less than AOMDV.

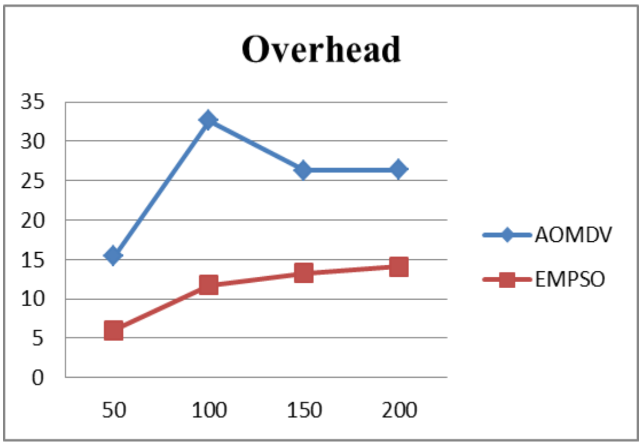

Figure 1.2: Overhead (Scenario-1)

c. Delay: This energy based protocol (EMPSO) performs better than AOMDV and achieves 41% improvement in Delay. The comparison of these protocols by varying nodes is as given in table 1.4.

Table 1.4: Delay

	Delay			
	50	100	150	200
AOMDV	0.07	0.06	0.04	0.05
EMPSO	0.02	0.03	0.03	0.04

Figure 1.3 shows the performance of both protocols. This figure shows that Delay increases with the increase number of nodes but less than AOMDV.

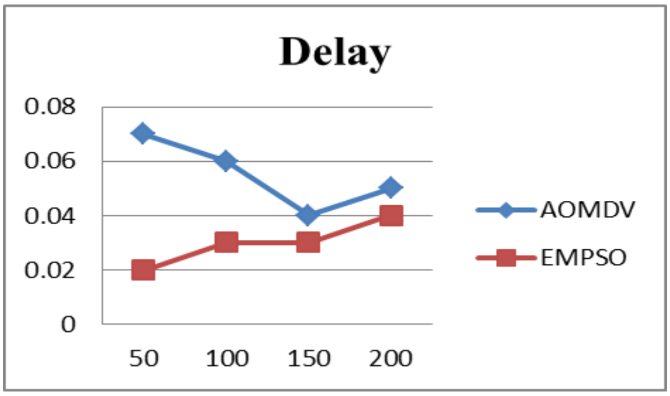

Figure 1.3: Delay (Scenario-1)

d. Throughput: This energy based protocol (EMPSO) performs better than AOMDV and achieves 57% improvement in Delay. The comparison of these protocols by varying nodes is as given in table 1.5.

Table 1.5: Throughput

	Throughput			
	50	**100**	**150**	**200**
AOMDV	51.55	56.54	47.59	59.18
EMPSO	112.43	127.31	129.27	132.731

Figure 1.4 shows the performance of both protocols. This figure shows that Throughput increases with the increase number of nodes and more than AOMDV.

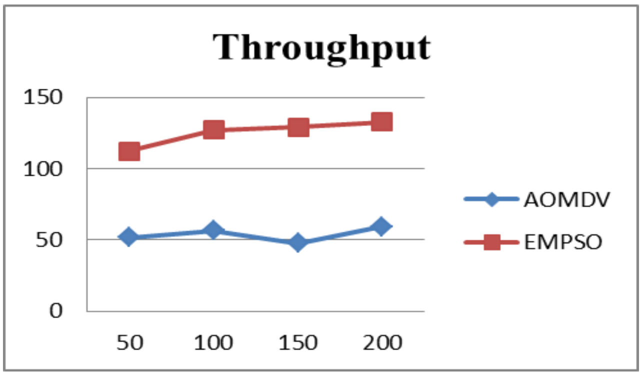

Figure 1.4: Throughput (Scenario-1)

e. Total Energy Consumption: This energy based protocol (EMPSO) performs better than AOMDV and achieves 16% improvement in Delay. The comparison of these protocols by varying nodes is as given in table 1.6.

Table 1.6: Total Energy Consumption

	Total Energy			
	50	**100**	**150**	**200**
AOMDV	4896.06	9764.28	14869.5	19835.8
EMPSO	3224.28	8926.63	13362.63	17374.7

Figure 1.5 shows the performance of both protocols. This figure shows that Total Energy consumption increases by increasing number of nodes but less than AOMDV.

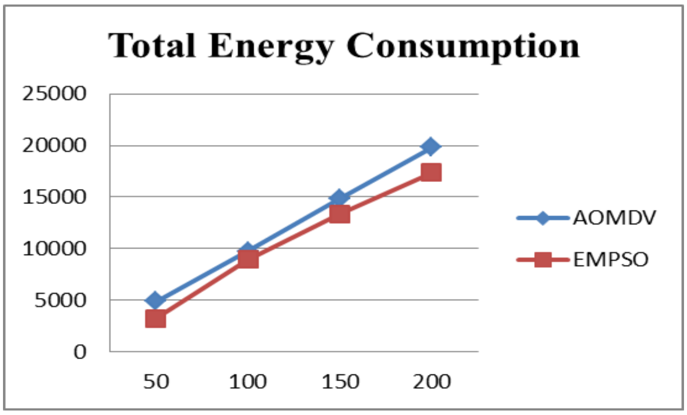

Figure 1.5: Total Energy Consumption (Scenario-1)

1.2.2 Scenario2: Varying Packet Size

To test the performance of the protocols 50 nodes are deployed with variable packet size in the area of 1000x1000 m^2 with maximum speed of 50m/s. Simulation is carried out using CBR traffic with maximum 40 connections. Other parameters are as given in the table 1.7.

Table 1.7: Simulation Setup

Simulation Parameters	Values
Area	1000x1000
No. of nodes	50
Speed	0~50m/s
Traffic	CBR
Packet Size	200,400,600,800,1000 bytes
Packet Rate	250k/s
Pause Time	500s
Simulation Time	1000s
Max Connection	40

Results Parameters:

a. Packet Delivery Ratio: This energy based protocol (EMPSO) performs better than AOMDV and achieves 33% improvement in Packet Delivery Ratio. The comparison of these protocols by varying packet rate is as given in table 1.8.

Table 1.8: Packet Delivery Ratio

	PDR				
	200	400	600	800	1000
AOMDV	49.2347	28.3298	25.6825	18.4943	23.0701
EMPSO	32.4732	40.2719	45.921	61.383	89.321

Figure 1.6 shows the performance of both protocols. This figure shows that Packet Delivery Ratio increases by increasing number of packets and more than AOMDV.

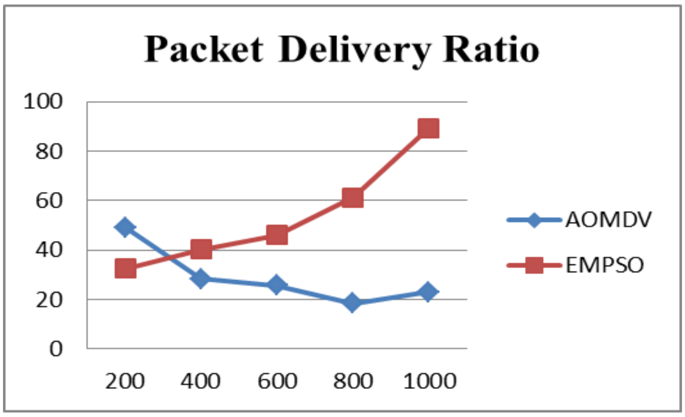

Figure 1.6: Packet Delivery Ratio (Scenario-2)

b. Overhead: This energy based protocol (EMPSO) performs better than AOMDV and achieves 21% improvement in Overhead. The comparison of these protocols by varying packet rate is as given in table 1.9.

Table 1.9: Overhead

	Overhead				
	200	400	600	800	1000
AOMDV	5.582	7.855	7.424	14.884	15.431
EMPSO	14.374	12.499	10.482	8.3092	6.038

Figure 1.7 shows the performance of both protocols. This figure shows that Overhead decreases by increasing number of packets and it is more than AOMDV in case of 200,400 and 600 packets but less in case of 800 and 1000 packets.

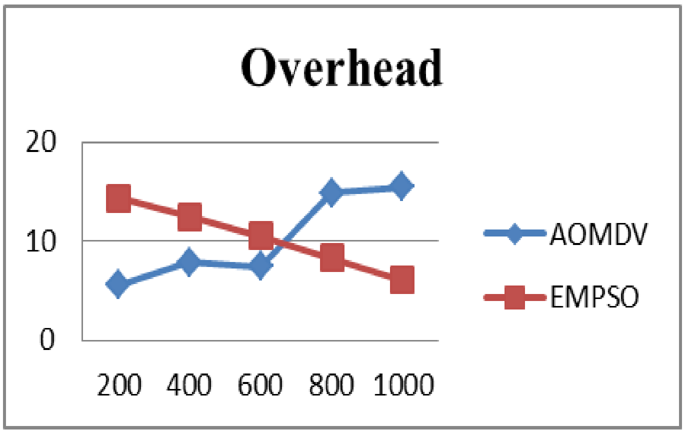

Figure 1.7: Overhead (Scenario-2)

c. Delay: This energy based protocol (EMPSO) performs better than AOMDV and achieves 49% improvement in delay. The comparison of these protocols by varying packet rate is as given in table 1.10.

Table 1.10: Delay

	Delay				
	200	400	600	800	1000
AOMDV	0.02	0.02	0.02	0.02	0.07
EMPSO	0.01	0.01	0.01	0.015	0.02

Figure 1.8 shows the performance of both protocols. This figure shows that delay increases by increasing number of packets but less than AOMDV.

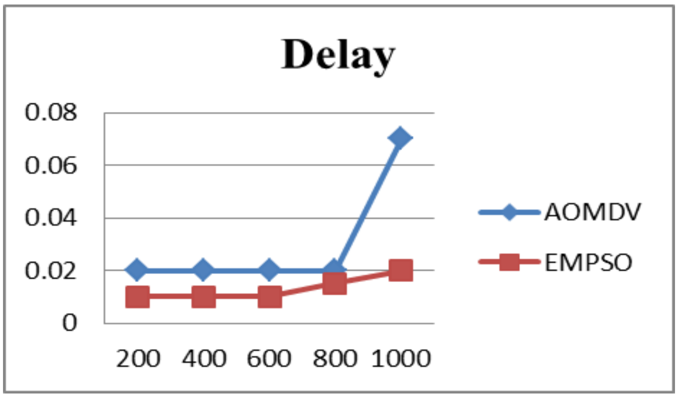

Figure 1.8: Delay (Scenario-2)

e. Throughput: This energy based protocol (EMPSO) performs better than AOMDV and achieves 33% improvement in Throughput. The comparison of these protocols by varying packet rate is as given in table 1.11.

Table 1.11: Throughput

	Throughput				
	200	400	600	800	1000
AOMDV	33.54	36.15	60.13	41.9	51.55
EMPSO	30.2	70.38	78.45	89.32	112.43

Figure 1.9 shows the performance of both protocols. This figure shows that Throughput increases by increasing number of packets and is more than AOMDV.

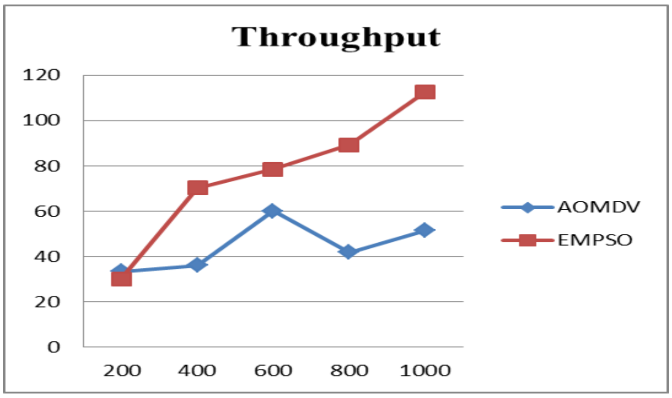

Figure 1.9: Throughput (Scenario-2)

f. Total Energy Consumption: This energy based protocol (EMPSO) performs better than AOMDV and achieves 25% improvement in Energy Consumption. The comparison of these protocols by varying packet rate is as given in table 1.12.

Table 1.12: Total Energy Consumption

	Total Energy				
	200	400	600	800	1000
AOMDV	4992.59	4866.33	4823.25	4778.94	4896.06
EMPSO	4137.27	3822.38	3528.27	3429.28	3224.28

Figure 1.10 shows the performance of both protocols. This figure shows that Energy Consumption decreases by increasing number of packets and is less than AOMDV.

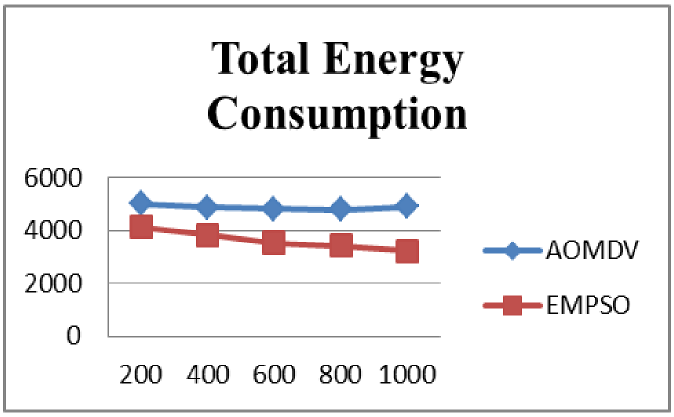

Figure 1.10: Total Energy Consumption (Scenario-2)

1.2.3 Scenario3: Varying Speed

To test the performance of the protocols 50 nodes are deployed with variable speed in the area of 1000x1000 m^2 with fixed packet rate. Simulation is carried out using CBR traffic with maximum 40 connections. Other parameters are as given in the table 1.13.

Table 1.13: Simulation Setup

Simulation Parameters	**Values**
Area	1000x1000
No. of nodes	50
Speed	10,20,30,40,50 m/s
Traffic	CBR
Packet Size	1000 bytes
Packet Rate	250k/s
Pause Time	500s
Simulation Time	1000s
Max Connection	40

Results Parameters:

a. Packet Delivery Ratio: This energy based protocol (EMPSO) performs better than AOMDV and achieves 75% improvement in Packet Delivery Ratio. The comparison of these protocols by varying speed is as given in table 1.14.

Table 1.14: Packet Delivery Ratio

	PDR				
	10	20	30	40	50
AOMDV	23.3564	10.2126	27.8491	19.4062	14.9668
EMPSO	70.3293	73.492	81.859	84.2929	85.392

Figure 1.11 shows the performance of both protocols. This figure shows that Packet Delivery Ratio increases by increasing speed and is more than AOMDV.

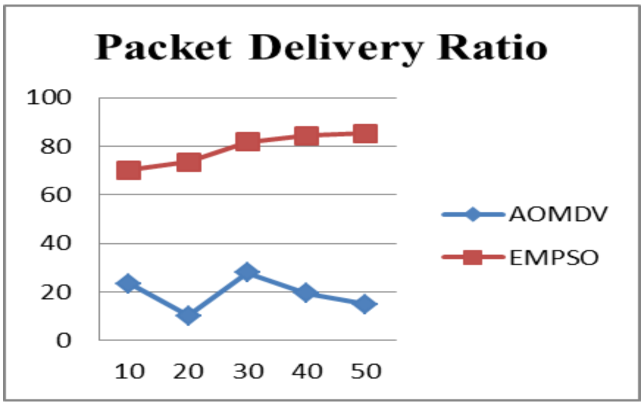

Figure 1.11: Packet Delivery Ratio (Scenario-3)

b. Overhead: This energy based protocol (EMPSO) performs better than AOMDV and achieves 56% improvement in Overhead. The comparison of these protocols by varying speed is as given in table 1.15.

1.15 Overhead Table

	Overhead				
	10	20	30	40	50
AOMDV	9.269	23.539	8.17	13.07	15.545
EMPSO	3.292	3.928	5.391	6.927	7.037

Figure 1.12 shows the performance of both protocols. This figure shows that Overhead increases b increasing speed but it is less than AOMDV.

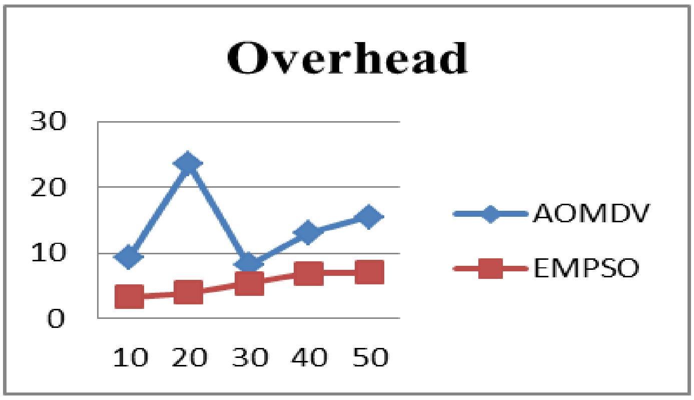

Figure 1.12: Overhead (Scenario-3)

c. Delay: This energy based protocol (EMPSO) performs better than AOMDV and achieves 7% improvement in Delay. The comparison of these protocols by varying speed is as given in table 1.16.

Table 1.16: Delay

	Delay				
	10	20	30	40	50
AOMDV	0.07	0.06	0.04	0.03	0.05
EMPSO	0.02	0.04	0.04	0.05	0.05

Figure 1.13 shows the performance of both protocols. This figure shows that Delay increases by increasing speed and it is more than AOMDV on high speed value and less in low speed.

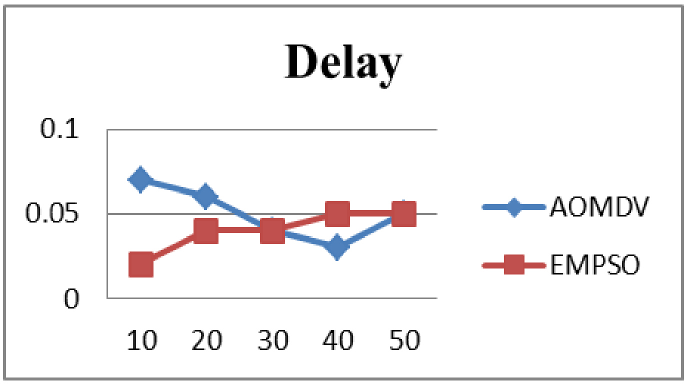

Figure 1.13: Delay (Scenario-3)

d. Throughput: This energy based protocol (EMPSO) performs better than AOMDV and achieves 27% improvement in Throughput. The comparison of these protocols by varying speed is as given in table 1.17.

Table 1.17: Throughput

	Throughput				
	10	20	30	40	50
AOMDV	77.9	40.63	80.91	50.17	46.04
EMPSO	78.02	80.27	81.29	85.38	87.92

Figure 1.14 shows the performance of both protocols. This figure shows that Throughput increases by increasing speed and it is more than AOMDV even on high speed value.

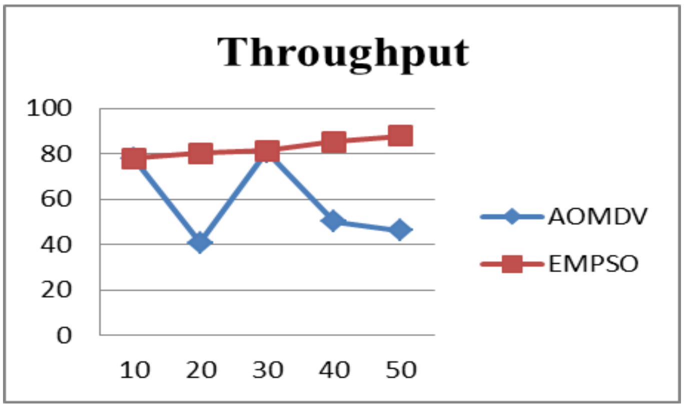

Figure 4.14: Throughput (Scenario-3)

e. Total Energy Consumption: This energy based protocol (EMPSO) performs better than AOMDV and achieves 5% improvement in Total Energy Consumption. The comparison of these protocols by varying speed is as given in table 1.18.

Table 1.18: Total Energy Consumption

	Total Energy				
	10	20	30	40	50
AOMDV	4988.97	4837.62	5057.01	5047.23	5012.22
EMPSO	4628.41	4583.28	4729.18	4838.21	4892.84

Figure 1.15 shows the performance of both protocols. This figure shows that Total Energy consumption increases by increasing speed and it is less than AOMDV even on high speed value.

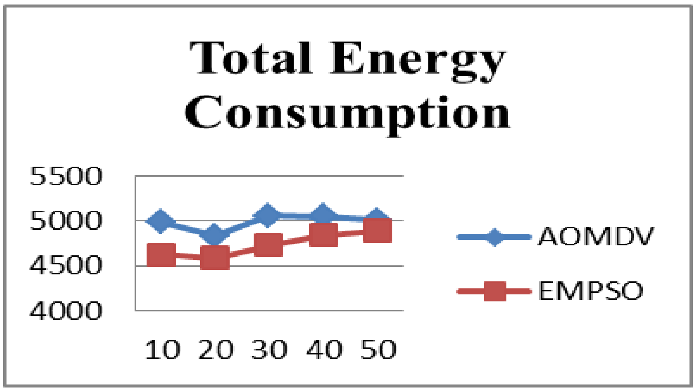

Figure 1.15: Total Energy Consumption (Scenario-3)

3. CONCLUSIONS

In this paper, the analysis of the base protocol which is based on Energy-Aware Multipath Routing Scheme with Particle Swarm Optimization is done. This protocol is implemented and tested on three different scenarios where its performance is measured in terms of different parameters. The resultant parameters show that this energy based protocol performs better than AOMDV in all aspects. So, this protocol will be used in further work to enhance the performance of Mobile Ad hoc Network in terms of energy.

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