Energy-Aware-AODV: Optimized Route Selection Process based on Ant Colony Optimization – Bacterial Foraging Algorithm (ACO-BFA)

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Abstract:* *Mobile ad-hoc network (MANET) is an emerging domain among the researchers, which is an ensemble scheme of numerous mobile nodes and it works without any base station. In ad hoc networks, usage of energy is the main issue, and the energy level of the node is not considered by Ad-hoc On-demand Distance Vector (AODV) during the route discovery phase. The node with minimum energy in the transmission area will fail transmission and packet dropping. The link failure re-initiates the route request (RREQ) and consumption of energy also high. To enhance this issue, an optimized routing strategy is introduced by the Ant Colony Optimization with Bacterial Foraging Algorithm (ACO-BFA) for AODV. The routing process is initiated by ACO and a high probability routing path is assigned to bacteria. The routing is enhanced by the ACO-BFA technique and the simulation analysis shows that the proposed technique outperforms the existing state-of-art AODV routing techniques.

Keywords:* *AODV, route selection, energy consumption, MANET, bandwidth, proactive, ACO, and BFA.

1. INTRODUCTION

MANET encompasses numerous mobile nodes, which communicate with the other nodes in the network. Any base station or centralized administration is not necessary for the data transmission among the mobile nodes in the MANET whereas it is identified as an infrastructure-less, self-configuring, and self-organizing network [1]. The nodes in the network are permitted to move freely and hence, the transmission pattern is random. Every node in the MANET will act as a host and router based on the need in the process of routing. The data transmission path electing is routing and it has two significant operations. Initially, it identifies the optimal path for routing and subsequently, transmits the data from source to destination [2, 3].

The dynamic nature of mobile nodes in the transmission area rapidly alters the topology of the network in MANET. Consequently, routing protocols are developed and utilized for managing the data packets among the routes, and an optimal path is chosen for the data effective data transmission [4]. The selection of optimal routes transmits the data to the exact destination and it plays a significant role in wireless communication. Generally, the nodes in the ad-hoc are battery-powered and hold a limited amount of energy. Recharging or replacing the power source is a complicated process [5]. Energy consumption, lack of infrastructure, and less utilization of wireless channels are the drawbacks of MANET.

MANET protocols are categorized as pro-active, reactive, and hybrid protocols. The table-driven or pro-active protocol maintains the entire network's topology and later, the information is utilized for data transmission. The on-demand or reactive protocol does not preserve any topology information whereas it builds a network based on on-demand. A hybrid routing protocol is a combination of both reactive and proactive protocols [4, 5]. AODV is a reactive protocol, which activates the node whenever the node initiates data transmission and the optimal route detection is not possible [6]. The intermediary nodes in the AODV have made unpredictable routes due to the incidence of old sequence numbers to the source instead of the latest numbers and the redundant route reply (RREP) for an RREQ causes high overhead [7, 8].

In a wireless network, the usage of AODV is highly motivated by the restricted bandwidth and it uses the on-demand mechanism from other MANET protocols. The main advantage of AODV over other MANET protocols is the information about the source route is not included with every data packet. The routing overhead is highly minimized by the AODV protocol. AODV necessitated frequent updates and it utilizes high bandwidth. The route is identified by the wide network broadcasting [9,10].

From the investigation of diverse factors of AODV protocol, it is identified that the enrichment of battery capacity or minimization of energy consumption is necessary for AODV [11]. During, communication, energy is exhausted by the active or inactive state of transmission. Therefore, an energy-aware routing protocol is necessary to determine the energy efficiency during an active state. The routing process necessitates a high degree of mobile nodes and it is highly power consuming that makes the routing a challenging process [12, 13]. The routing process is optimized by the hybridized bio-inspired techniques Ant Colony Optimization with Bacterial Foraging Algorithm (ACO-BFA) for AODV.

AODV is a reactive and loop-free protocol for ad-hoc networks. It is developed to be self-starting in an atmosphere of numerous mobile nodes, withstanding a variety of behaviors in the network namely packet losses, link failures, and node mobility. The shortest route in the network may be lost due to the incidence of traffic during the process of path discovery. This may lead to the usage of vast energy while transmitting the data and an effective approach is necessary to overcome this issue. The main objective of this research article is, to identify the optimized route for transmitting the data, an effective routing process is established and to minimize energy consumption by utilizing certain effective strategies during data transmission.

The remaining research article is organized as follows: various reviews on the AODV protocol are elucidated in Section 2, proposed energy-aware ACO-based BFA is given in Section 3, simulation analysis and investigation is given in Section 4 and the article is concluded in Section 5.

2. MATERIALS AND METHODOLOGIES

The wireless network is a set of mobile nodes deployed geographically and equipped with a wireless interface. Energy consumption and the accomplishment of service is a complicated process that is rectified by the Energy and Quality of Service supported AODV. The process of routing is initiated by considering the node's energy and data packet nature. This technique mainly focuses on the avoidance of connectivity break and retransmission. EQ-AODV is applicable only for certain scenarios and it also considers limited communication parameters [14].

Efficient Power Aware Ad-hoc on-Demand Distance Vector is a modified network of AODV. In EPAAODV, the enhancement of network lifetime is concentrated and the transmission is initiated based on the range of hop count and residual energy. The maintenance of routing information is complicated and the failure of transmission may occur due to inadequate information about hop count and residual energy [15]. MANET protocols are investigated and contrasted in terms of energy consumption by the nodes during the data transmission.

The context of a wireless network is resource-constrained, which necessitated the comparison of simulation among the MANET protocols. From the simulation investigation, the author [16], identified that the AODV consumes minimum energy for the big and moderated network. But in the tiny region and moderately high region, energy consumption is relatively high when compared to other MANET protocols. In the route identification process of AODV, the energy level of the node is not considered and assigned with data for transmission.

The node with less energy may exhaust at any time during the transmission that makes the failure of transmission. The re-initiation of RREQ has been accomplished again and again it utilizes energy [17]. Bio-Inspired optimization techniques are introduced for route optimization in AODV. The energy utilization of nodes is considered during the process of searching the routes to the destination. An ACO technique is developed for AODV and the transmission accuracy is not considered in ACO [18].

Energy Efficient AODV (EE-AODV) enhances the mechanism of RREP and RREQ, which in turn saves energy usage. The energy level of every node is evaluated and the node with sufficient energy will act as an intermediary node. The nodes with minimum energy are assigned as intermediary nodes [19]. In the geographic routing protocol, the routing is optimized by an intelligent water drop technique which in turn minimizes the energy consumption [20]. The energy consumption and routing reliability are improved in the dynamic source routing protocol are enhanced by the ant and bee colony optimization [21]. Route optimization is not considered in this technique. Diverse AODV protocols and enhancement techniques are surveyed in this section. Based on the limitations in the existing technique, an optimized routing technique is formulated in the proposed ACO-BFA technique.

3. RESULTS AND DISCUSSIONS

ACO mimics the pheromone scheme of ants and the stochastic search method is employed, which probabilistically searches the sample space [22]. The route discovery strategy of AODV is initiated with P number of paths searched and the initial population is generated as C^0 with the population size of P. So the initial ant of individual is indicated as

Where x=1, 2, …….. P, the population size is P.

Initially, request (RREQ_ANT) is sent to the nodes in the neighbor location and the forwarding process is accomplished by the ACO technique. The forwarding process generates a reverse link to the originator RREQ_ANT. The sequence number on every node is stated as an ant. The generation of the initial population is given in equation 1. The selection of routes is initiated by the fitness value. The individual fitness of x is $ft(c_x)$, the chosen probability Pb_{cx} of every individual ant is estimated as,

AODV protocol selects the optimal route to transmit the data where the minimum count of the hop is considered in the route selection. The fitness of individual ant is estimated as follows,

where the count of the hop for individual ant c_x in the population is indicated H (c_x).hop_size.

where the count of the node in every path is H_x, the arbitrary constant is denoted by $A_{CST,}$ and the cost of every node () is denoted that is expressed in the nodes of wireless network E_{TI}(b, dis) and E_{DI}(b, dis). The estimation of cost is as follows,

The length of the routing path determines the information delivery in a distinct time and the level of node energy defines the survival duration of the routing path whereas these are indispensable in determining the path survival. To balance these values, fitness is estimated based on a balanced selection mechanism and ½ is assigned to both w_1 and w_2.

The energy consumption may be high when the route uses large hops and the lifetime of the network is also a critical constrain for energy consumption. Hence, these two constraints are included in the estimation of fitness. The fitness value estimation by hop is in Equation 3, the fitness value estimation by energy is shown in Equation 4 and the comprehensive fitness calculation is given in Equation 6.

The pheromone count and signal strength are calculated to identify the routing probability. The selection of subsequent hop is attained using the value of pheromone. The pheromone value of link among the p and q that is estimated as,

where the strength of the signal among the link p and q is indicated as RS_{pq}, the remaining energy in the node q is indicated as $E_{q,}$ and the count of the hop that the RREQ_ANT is traversed from the source q via p.

The strength of the signal determines the link's reliability that can forecast the breakage of the link. The signal strength received (SSR) is estimated as [23],

Where the gain of transmitting antenna is indicated as, the transmitting antenna's transmission power is indicated as , the wavelength in MANET is indicated as . The route request initialization process is given in Algorithm 1.

Algorithm 1. Route Request Initialization

```
At source node
        Data_send(source, destination)
        {
        if(route!=0)
                send data to destination
        else
                send RREQ_ANT(destination)
        }
send RREQ_ANT(destination)
        {
                If(SSR>=Threshold_Signal)
                {
                 Update table
```

```
        }
    }
```

The pheromone and signal strength is estimated to identify the route with high probability, which is assigned as an initial point for bacteria and identifies the optimal path to transmit the data. The bacteria is relevant to a single route and the size of the obtained probable route from ACO is E. The E.Coli bacteria is performed its operation through swimming and trembling whereas searching for nodes in a similar direction and random direction respectively [25]. The node with inadequate capacity to transmit data are removed and the bacterium moves along the entire network to search for the appropriate node. The chemokine operation is initiated to estimate the progression direction where the fitness value is enhanced. The chemokine operation is estimated as,

Where the fitness of the flora is indicated as, the direction of swing is indicated as, the alteration of direction is indicated as and the unit step is indicated as that is after the direction adjustment.

The bacteria's health is estimated based on the fitness function of bacteria and the bacteria with minimum health is removed and the bacteria with higher health is reproduced. The global optimum solution is identified by skipping the local optimum solution. The bacteria's health is as follows,

Where health function of a bacteria is given as that is the energy function of the bacteria . The energy of the bacteria (node) is determined by the health of the bacteria. Once the value reaches $b=N_{re}$, then the reproduction is accomplished. The migration is initiated at specified probability and reallocated randomly in the new range of search. The migration is attained until it reaches optimization. The ACO-BFA technique is applied to the AODV routing protocol to optimize the selection process of routing of the AODV protocol. It effectively controls the overhead and reduces the usage of energy and delay in transmission. The BFA based optimization is given in Algorithm 2.

Algorithm 2. Route Request Initialization

```
Procedure fitness function ()
        Obtaining available paths from ACO
while(i<=P)                                   //stop criteria
        get path
        evaluate fitness function
        Energy and Hop calculation
      If(Energy and Hop Value>Threshold)
          Chemokine operation
          Reproduction
          Event dispersal
```

```
        End if
Increment i
End while
End
```

4. SIMULATION ANALYSIS

In this section, simulation performance of ACO-BFA for AODV is evaluated in diversified simulation context is illustrated. Simulation of AODV techniques is performed using Network Simulator 2 (NS2) where OTcl acts as an interpreter as well as a front end and C++ as a backend [25]. NS 2 supports numerous wireless network-based routing protocols. The comparison of simulation performance is accomplished with the existing techniques namely AODV [17], Enhanced Ant-AODV [18], and EE-AODV [19]. The performance of the protocols is estimated by the end-to-end delay, overhead, network lifetime, and energy consumption. The values for these performance metrics are acquired for different nodes. The simulation setup of the network is depicted in Table 1.

Table1 Simulation Set-up

Simulation Parameter	Values
Channel Type	Wireless Channel
Antenna	Omni Antenna
MAC Protocol	IEEE 802.11
Simulation Area	1800m*1800m
Application Type	CBR
Application Agent	UDP
Initial Energy	100J
No of Simulation Node	250
Total Simulation Time	15 Minutes

4.1. End-to-End delay

The incidence of delay during the transmission of the data packet from the source node to destination is stated End to End Delay. The incidence of delay in transmission influences the performance of the transmission and the protocol with minimal delay is the effective technique. End to End delay of ACO-BFA is compared with existing algorithms namely AODV [17], Enhanced Ant-AODV [18], and EE-AODV [19]. The simulation outcomes are depicted in Table 2 and the results are illustrated in Figure 1. From the observation of the simulation analysis, it is identified that the proposed technique shows better performance with minimum delay. The delay is equated as follows, where S_p indicates the packet sent at dn^{th} time, R_p indicates the packet received at dn^{th} time, and the count of the data packet are indicated as DN. The delay is indicated for delay per millisecond (delay/ms).

Table 2 Comparison of Average End-to-End delay

No of Nodes	Existing Technique			Proposed Technique
	AODV	Ant-AODV	EE-AODV	ACO-BFA
50	18.6	16.1	16	15.8
100	49.2	36.6	35.2	32.1
150	56.4	45.2	44.1	43.2
200	62.8	51.9	51.3	50.9
250	75.4	59.9	58.9	56.8

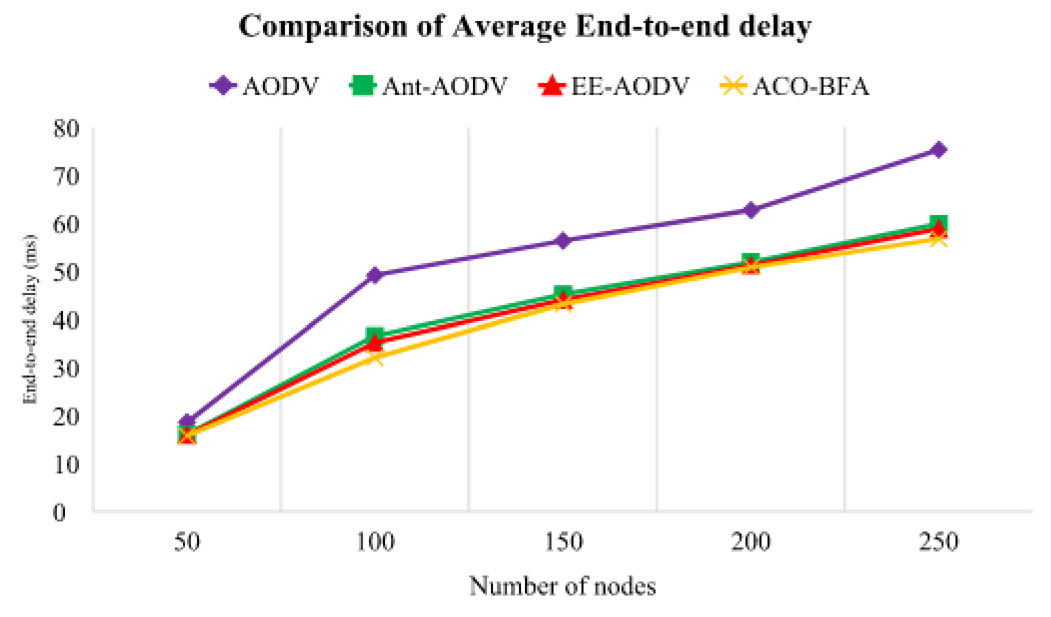

Figure 1 Comparision of Average End to End Delay

From Figure 1, it is identified that the ACO-BFA has a minimum delay when compared to the existing techniques. The comparison is made for a different number of nodes and with the existing techniques namely AODV, Enhanced Ant-AODV, and EE-AODV. The ACO-BFA for AODV accomplishes the data transmission via optimal route, which makes less transmission delay and it outperforms the existing techniques.

4.2. Routing overhead

The scalability of the protocol is measured by the routing load. The routing overhead is estimated by the total count of the packet transmitted is divided by the success rate of data packets. The high adaptive nature of ACO-BA controls the load and other existing protocols re-initiate the discovery process once the link failure occurred. This makes high routing overhead in existing protocol and minimum in the proposed technique. The routing overhead of ACO-BFA is compared with existing algorithms namely AODV [17], Enhanced Ant-AODV [18], and EE-AODV [19]. The simulation outcomes are depicted in Table 3 and the results are illustrated in Figure 2. From the observation of the simulation analysis, it is identified that the proposed technique shows better performance with minimum routing overhead. It is equated as follows,

Table 3 Comparison of Routing Overhead

No of Nodes	Existing Technique			Proposed Technique
	AODV	Ant-AODV	EE-AODV	ACO-BFA
50	0.29	0.27	0.26	0.19
100	0.32	0.31	0.29	0.28
150	0.56	0.41	0.39	0.30
200	0.61	0.49	0.42	0.33
250	0.71	0.55	0.52	0.41

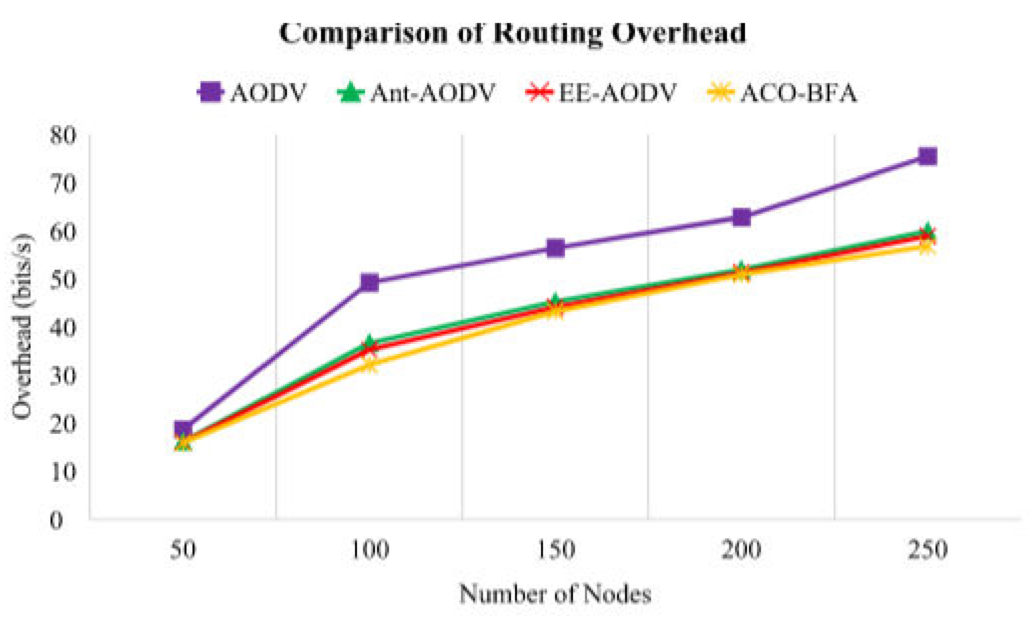

Figure 2 Comparision of Routing Overhead

From Figure 2, it is identified that the ACO-BFA has minimum routing overhead when compared to the existing techniques. The comparison is made for a different number of nodes and with the existing techniques namely AODV, Enhanced Ant-AODV, and EEAODV. The ACO-BFA for AODV accomplishes the data transmission via optimal route, which makes less routing overhead and outperforms the existing techniques.

4.3. Network lifetime

The functional duration of WSN is network lifetime and the nodes are completely operative during that period. The network lifetime is the interval at which the initial node in the transmission area exhausts energy to transmit a packet and the node turned to be inactive. It fails to accomplish certain functionalities. In the ACO-BFA method, the transmission link and its connectivity are effectively established and the lifetime is also enriched. The network lifetime of ACO-BFA is compared with existing algorithms namely AODV [17], Enhanced Ant-AODV [18], and EE-AODV [19]. The simulation outcomes are depicted in Table 4 and the result is displayed in Figure 3. The network lifetime estimation is equated as,

Table 4 Comparison of Network Lifetime

No of Nodes	Existing Technique			Proposed Technique
	AODV	Ant-AODV	EE-AODV	ACO-BFA
50	850	821	799	756
100	721	711	692	682
150	699	690	652	641
200	651	641	621	611
250	599	591	571	553

4.4. Energy consumption

The sum of the energy is consumed by all packets in the entire network is stated as energy consumption. The energy exploitation of the node in the simulation environment is estimated by utilizing the variation among the current level of energy to the initial level of energy. If a node in the transmission area reaches an energy level to zero, it cannot transfer or collect any more data packets. Energy consumption of ACO-BFA is compared with existing algorithms namely optimized AODV [17], Enhanced Ant-AODV [18], and EE-AODV [19]. The simulation outcomes are depicted in Table 5 and the results are illustrated in Figure 4. From the observation of the simulation analysis, it is identified that the ACO-BFA shows better performance with low energy consumption. The energy consumption is equated as follows,

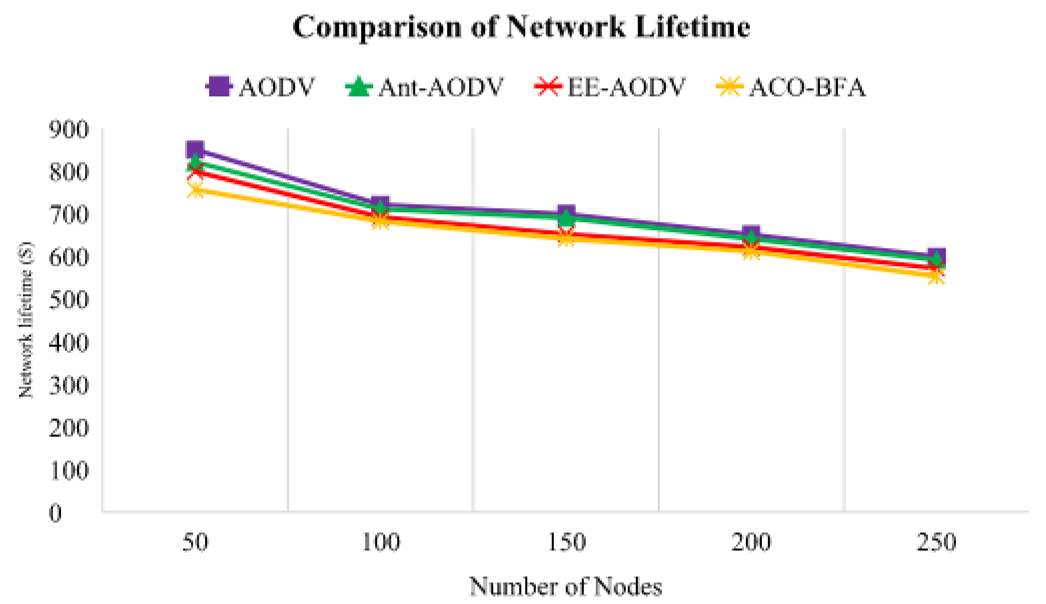

Figure 3 Comparision of Average Network Life time

From Figure 3, it is identified that the ACO-BFA has network lifetime is high when compared to the existing techniques. The comparison is made for a different number of nodes and with the existing techniques namely AODV, Enhanced Ant-AODV, and EE-AODV. The ACO-BFA for AODV accomplishes the data transmission via optimal route, which makes enhances the network lifetime and it outperforms the existing techniques.

Table 5 Comparison of Average Energy Consumption

No of Nodes	Existing Technique			Proposed Technique
	AODV	Ant-AODV	EE-AODV	ACO-BFA
50	0.78	0.75	0.71	0.63
100	0.65	0.64	0.61	0.58
150	0.55	0.54	0.51	0.45
200	0.43	0.42	0.39	0.25
250	0.31	0.30	0.27	0.21

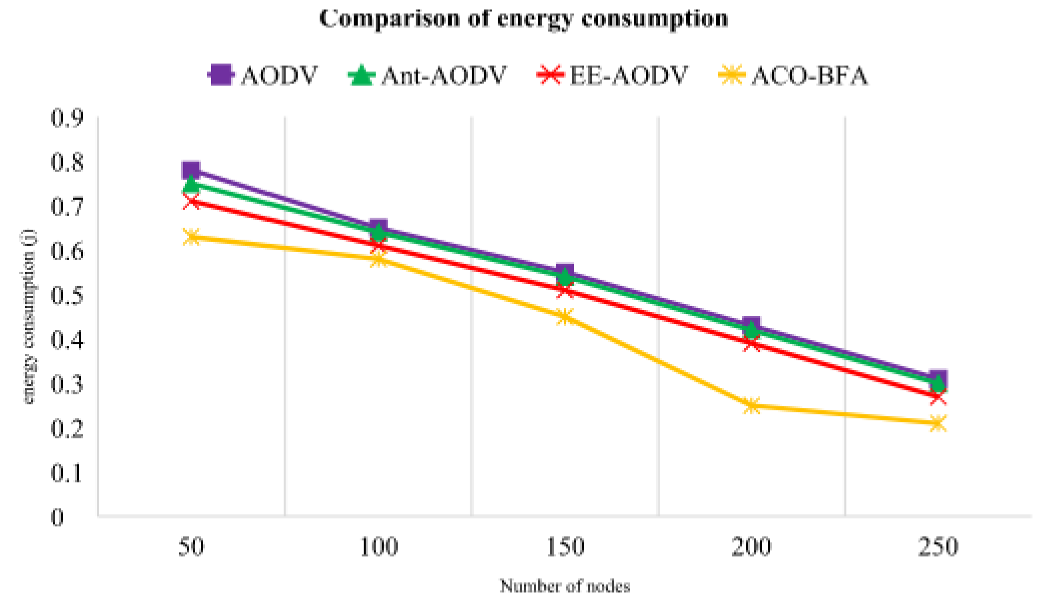

Figure 4 Comparision of Energy Consumption

From Figure 4, it is identified that the ACO-BFA has minimum energy consumption when compared to the existing techniques. The comparison is made for the different number of nodes and with the existing techniques namely AODV, Enhanced Ant-AODV, and EE-AODV. The ACO-BFA for AODV accomplishes the data transmission via optimal route, which makes less energy consumption and it outperforms the existing techniques.

5. CONCLUSION

In this research article, data transmission issues in the AODV protocol are considered and it is rectified by the proposed ACO-BFA technique. The huge energy consumption is a drawback of the AODV protocol and it is enhanced by an efficient routing process. The energy utilization of nodes is considered during the process of searching the routes to the destination. An Ant Colony Optimization – Bacterial Foraging Algorithm (ACO-BFA) is designed to select the optimized routes. The paths are initiated by the ACO technique and it identifies the route with high probability that is considered as an initial point of bacteria where the optimal path is identified. The optimization strategy of ACO-BFA has enhanced the route selection and states the convergence to the global optimum solution. The simulation results of the proposed technique ACO-BFA are compared with existing techniques namely AODV, Enhanced Ant-AODV, and EE-AODV. The simulation analysis shows that the ACO-BFA outperforms the existing state-of-art AODV routing techniques.

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