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Delay Aware Routing Protocol Using Optimized AODV with BBO for MPLS-MANET

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Abstract: Mobile Ad Hoc Network (MANET) is a wireless network that does not have any fixed structure. MANET is a collection of independent mobile nodes that can communicate with each other through radio waves. In conventional Internet Protocol (IP) forwarding, each router creates forwarding decision on the basis of IP header information. The router has to analyse the packet and routing table at each hop to take the decision for data transmission. Since, inappropriate decisions in data transmission causes delay in packet delivery. This can be overcome with the help of a special feature of Multiprotocol Label Switching (MPLS) called Label switching. MPLS is a switching mechanism that plays a good role in routing, switching and forwarding using small labels. The MPLS is integrated into MANET to improve network performance. In this paper, an effective routing strategy is introduced to reduce the transmission time between routers during the data transmission. Here the Ad Hoc On-Demand Distance Vector (AODV) with Biogeography Based Optimization (BBO) based routing method is used to identify the optimal route among the routers of the MPLS based MANET. The proposed methodology is named as AODV-BBO. Three different objective functions are considered in this routing strategy viz., residual energy, distance and number of hops. Moreover, the rerouting is performed when the node or link failure occurs in the network. This rerouting is used to overcome the packet drop through the MPLS based MANET. The performance of AODV-BBO methodology is analysed in terms of percentage of alive nodes, dead nodes, energy consumption, end to end delay and bandwidth. The performance of the AODV-BBO methodology is compared with two existing methods P2R2 and PS-ROGR. Result showed that, the energy consumption of the AODV-BBO methodology with 400 nodes is 536.52 J, which is less compared to the PS-ROGR method.

Keywords: End to end delay, Energy consumption, Mobile ad hoc network, Multiprotocol label switching, Biogeography based optimization.

1. Introduction

A mobile ad hoc network (MANET) is a collection of mobile hosts, which can communicate with the help of intermediate mobile hosts without utilizing a fixed infrastructure and centralized administration [1]. Mobile devices in a MANET come in different sizes and shapes, have varying transmission/receiving and processing capabilities and could operate across different frequency bands [2]. The MANET is specifically used in the military/search, rescue and other tactical situations where cellular infrastructure is not available or not reliable [3]. The challenges faced by the MANET are given as follows: In MANETs the nodes are free to move randomly and a node may join or leave the multicast tree at any time. Hence, maintaining group membership function and building the optimal multicast tree is challenging in wireless MANETs. The dynamic topology of the MANET leads to network partition and unreliability [4, 5]. Additionally, limited battery power, unpredictable mobility and large variation of received signal strength in nodes of MANETs create link and node vulnerability and instability [6]. Hence, Multi-Protocol Label Switching (MPLS) is incorporated in MANET to overcome the previously mentioned problems.

The integration of MANET with MPLS leads to improve the energy efficiency and end-to-end delay in the network [7]. MPLS can provide a fast packet forwarding with better Quality of Service (QoS). MPLS performs across a variety of physical layers to enable efficient data forwarding together with the reservation of bandwidth for traffic flows with different QoS requirements [8]. The MPLS network offers a connection-oriented data transferring services based on Label Switched Paths (LSPs). This data transmission is used to overcome the problem of Internet unreliability and the increase in the demands of better connectivity and quality [9, 10]. The LSP of MPLS forwards the packets over the network based on certain traffic rules [11]. The conventional routing protocols used in the MANET are mentioned as follows: binary particle swarm optimization based temporally ordered routing algorithm [12], efficient and stable multipath routing [13], minimal energy consumption with optimized routing [14] and MAC routing protocol in the clustered network [15], etc. The important contributions of this AODV-BBO methodology are stated as follows:

- The MPLS is integrated into the MANET to enhance the performance of the dynamic topology of the network.
- The effective route among the MPLS-MANET is generated based on the combination of AODV with BBO. Here AODV floods the RREQ messages over MPLS-MANET to identify the possible paths. Then the BBO is used to select the optimized path from the paths of AODV.
- The end-to-end delay and energy consumption of the MPLS-MANET is reduced by identifying the shortest path through the MPLS-MANET. The optimized shortest path is generated by considering distance, energy and the number of hops during route generation.

The organization of this research paper is given as follows: The section 2 provides the literature survey about the existing routing protocols used in MANET. The multiprotocol label switching is described in the section 3. The proposed AODV-BBO based route generation in MPLS-MANET is clearly explained in section 4. The experimental and comparative results of AODV-BBO methodology are given in section 5. Finally, the conclusion is made in section 6.

2. Literature survey

The literature survey about the recent routing protocols generated for the MANET are described in this section.

Chaudhry, R., Tapaswi, S. and Kumar, N [16] presented the geographical routing that is the combination of Forwarding Search Space (FSS) heuristic and Adaptive Particle Swarm Optimization (APSO). In source node, the forwarding zone was determined by using the FZ-PSO to transmit the data packets to the desired nodes. Here, three parameters, such as node degree, residual energy, angle and distance were used to evaluate the adjacent nodes. Thus it leads in generating the optimal transmission path from the source to the destination. The APSO utilization in the forwarding zone reduced the computational time and enhanced the convergence. In this work, valid particle generators were used due to the inadequate updation of velocity and position. Chettibi, S. and Chikhi, S [17] introduced the dynamic fuzzy energy state based AODV (DFES-AODV) routing protocol for MANET. The Mamdani Fuzzy Logic System (FLS) is used at each node for deciding the forwarding probability of the nodes in DFES-AODV route discovery phase. The FLS adaptivity is improved by using the dynamic membership function. The inputs to the FLS are energy drain rate and residual battery level of nodes. But this routing strategy fails to consider the distance among the nodes.

Jabbar, W.A., Ismail, M. and Nordin, R [18] presented the Multipath Battery and Mobility Aware routing scheme (MBMA-OLSR) in MANET. The MBMA-OLSR is based on the MP-OLSRv2. The advantages of MP-OLSRv2 possessed in the MBMA-OLSR are loop detection, topology sensing, and route recovery. The main operations are selection of multi-point relays and the evaluation of multiple paths. The paths were computed by combining the energy and mobility awareness techniques that used to reduce the energy consumption of the MANET. This MBMA-OLSR routing scheme considers only a residual battery energy and speed of the nodes.

Malathi, M. and Jayashri, S [19] introduced the power proficient reliable routing (P2R2) protocol. The channel capacity between the source and destination is considered in the P2R2 protocol. Direct communication between the source and the destination occurs when the capacity is greater than the threshold. If the capacity is lesser than the threshold, then it selects the multi-hop path. There are three parameters such as channel capacity, link quality and residual energy of the nodes used to select the nodes in the multi-hop path. Moreover, these parameters are used to avoid the route failure

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while performing data transmission. The performance of P2R2 scheme is mainly depending on the node's mobility.

C. Nallusamy, and A. Sabari [20] presented the Particle Swarm based Resource Optimized Geographic Routing (PS-ROGR) technique to prolong the network lifetime. The local best position is used to control the particle's (i.e. sensor node) movement in a network. In energy efficient routing, the node that has best global function is selected based on fitness value. The network lifetime was enhanced by selecting the node with high power and less distance. The fitness function was calculated for each particle only based on the distance, weighting factor and node power.

3. Multiprotocol label switching protocol

In Internet/ large networks, the MPLS is used to amplify the router's packet forwarding performance. MPLS uses a label switching process for exchanging the new header with IP lookup forwarding procedure. The frame relay protocols and label field in the asynchronous transfer mode are used in the MPLS header. The part of the packet header laid between the IP layer headers and link layer. The fields present in the MPLS header is given as follows:

- **Label:** A 20 bits field that contains the MPLS label.
- **Class of Service or Traffic Class:** a three-bit field that establishes the class of provided services.
- **Stack (S):** a single bit field, which demonstrates the end of the label, stack. If S is set, it means that the current label is the last one in the stack.
- **Time to Live (TTL):** 8 bits' field, which acts similarly to the TTL field in an IP header.

MPLS is developed for supporting traffic engineering and it provides the quality of service. The routers, which supports the MPLS, are referred as Label Switching Router (LSR). The label is selected from the free labels, when the LSR detects the FEC associated with the packet.

3.1 Overview of MPLS components

In MPLS, the labelled packets are transmitted by considering only the label instead of an entire IP table. Hence, the label switching and label lookup are faster than the routing information base lookup/ routing table. The Label Edge Routers (LER) are placed in the entry and exit of the MPLS network. The routers in the source and the destination are Ingress LER and Egress LER respectively. The LSR performs the data transmission based on the label. The labels are distributed by using the Label Distribution Protocol (LDP) and the network establishes the Label Switch Path (LSP) through the network. The network-based IP is created by the LSP and the traffics are routed over the certain paths of the MPLS. This MPLS protocol is integrated in the MANET to improve its performance.

4. AODV-BBO methodology

In this AODV-BBO methodology, AODV with biogeography based optimization is used to identify the optimum route for data transmission. The objective functions used in the routing algorithm are residual energy, number of hops and distance. The main objective of this AODV-BBO methodology is to reduce the end-to-end delay through the MPLS-MANET. The end-to-end delay through the network is reduced by considering the distance among the routers. The flowchart of the AODV-BBO methodology is shown in following Fig. 1.

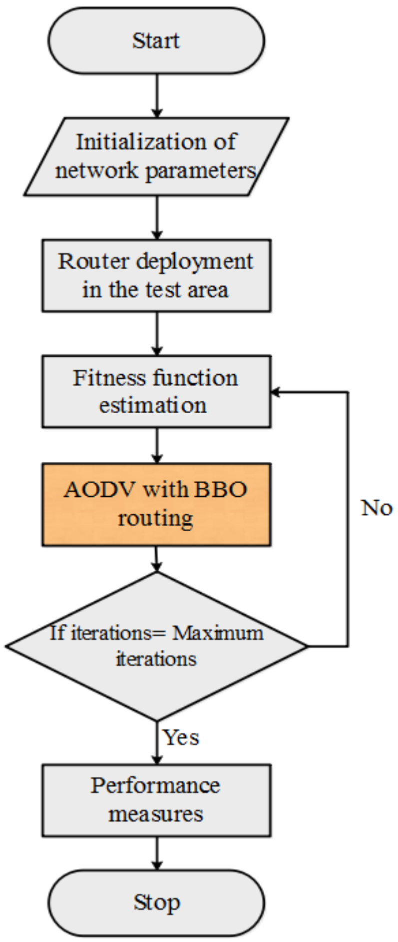

Figure.1 Block diagram of the AODV-BBO methodology

4.1 Route generation using AODV with BBO

Initially, the routers are deployed over the MPLS-MANET. The AODV selects the possible path from the source router to the destination router based on the information about the routers. Subsequently, the BBO is used to select the optimal path from possible paths of AODV. The combination of AODV and BBO selects the optimal route over the network.

4.1.1. Route discovery using AODV

The AODV routing protocol is used to detect the routes for new destinations, and this AODV does not require routers to maintain routes that are inactive. The faster and dynamic adaption to the changes in the network topology is the major advantage of AODV. The path discovery process is initiated for locating the adjacent node when the source router wants to transmit the data packets to the destination router. The message mechanisms used in the AODV routing protocol are route request (RREQ), route reply (RREP), and routing error (RERR).

Initially, the source router checks the routing table, whether it has any possible route to the destination. The data packets are directly transmitted to the destination, when the routing table has route for source router. If the route does not exist in the routing table, the RREQ message is broadcast over the network for starting the routing process to detect and establish the adequate routing. The intermediate and destination router sends the RREP in AODV route discovery process. The packets are transmitted back to the source by using the reverse route detected in the route discovery process. The reverse route to the source router is maintained by using the serial number of source router in the RREQ packet. If the source router transmits the RREQ packet to various destination routers, all routers of the network generate the reverse route to the source. The router establishes the address of the adjacent router of the first RREQ packet. The RREP packets are generated when the RREQ packet reaches the destination router. The transmission of RREP packets to the source router is performed by using the BBO technique. Thus leads to discover the optimum transmission path between the source to the destination. The clear description about BBO and route generation in BBO are given in the following section.

4.2 Route optimization using BBO

The shortest optimal path from the source router to the destination router is obtained based on the residual energy of each router, distance from the one router to another router and a number of hops.

4.1.2. Overview of biogeography based optimization (BBO)

BBO is a geographical way of assignment of biological species. Each geographical zone is represented by an index known as a Habitat Suitability index (HSI). Suitability Index Variable (SIV) is another index is used to represent the area of habitat and livelihood conditions. The fitness of each habitat is analogous to its HSI value and number of species. To improve the low HSI solution, it accepts features from high HSI solution. The emigration rate (μ) and immigration rate (λ) of the BBO is expressed in the following Eqs. (1) and (2) respectively.

$$\mu = \frac{E \times k}{n_s} \tag{1}$$

Where, E is the maximum emigration rate, k is the amount of species in the habitat and maximum number of species is n_s.

$$\lambda = I\left(1 - \frac{k}{n_s}\right) \tag{2}$$

Where, I is the maximum immigration rate. The operation of the BBO is explained as follows,

4.2.1.1. Migration

In BBO migration, each solution is represented by a n dimension vector known as a habitat. Each dimension in the habitat is considered to be an SIV. The goodness of a habitat is analogous to HSI value and number of species. To improve the solution, low HSI solution shares information with high HSI solution (similar as GA and PSO), whereas sharing is based on immigration (λ) and emigration rates (μ). In this process, two habitats are chosen from the population. Initially, habitat (H_i) is selected based on the immigration rate (λ_i), and other habitat (H_j) is selected using emigration rate (μ_j) . Afterward, the randomly selected SIVs have migrated from $H_j$solution and appears in H_i.

4.2.1.2. Mutation

In a geographical region, HSI of a habitat change suddenly due to some natural disasters and causes habitat deviation from its equilibrium position. Similar effect demonstrated in BBO using mutation operation. It is performed using the species count of each habitat as shown in Eq. (3) and (4). A probability is assigned to each habitat for mutation. If it is high, it means that there is a less chance for mutation and a solution is nearer to the optimized solution. If it is low, it means a higher chance for mutation and a solution is far away from the optimized solution.

$$P_S^h \begin{cases} -(\lambda_s + \mu_s)P_s + \mu_{s+1}P_{s+1}, & s = 0 \\ -(\lambda_s + \mu_s)P_s + Q & 1 \leq s \leq s_{max} - 1 \\ -(\lambda_s + \mu_s)P_s + \lambda_{s-1}P_{s-1}, & s = s_{max} \end{cases} \quad (3)$$

$$m(s) = m_{max}\left(\frac{1-P_s}{P_{max}}\right) \quad (4)$$

Where, $Q = \lambda_{s-1}P_{s-1} + \mu_{s+1}P_{s+1}$, $m(s)$ is mutation rate of s species, m_{max} is maximum mutation rate and P_{max} is maximum mutation probability.

4.2.1. Habitat representation and initialization of BBO

The habitats are represented based on the discovered paths from the AODV. Moreover, the dimension of each habitat is identical to the amount of routers present in the MPLS-MANET. Assume $H_i = (H_{i,1}(t), H_{i,2}(t), \ldots, H_{i,m}(t))$ is the i^{th} habitat of the BBO. Then the next hop for the source is $1 \leq NH \leq m$. Where NH is the next hop and m is the amount of routers in the network.

4.2.2. Fitness function evaluation

In this AODV-BBO methodology, three different values are formulated in the fitness function such as residual energy, distance from the one router to another router and a number of hops of each router.

4.2.1.3. Residual energy

The main objective of this AODV-BBO methodology is to consider the residual energy(R_e) of the routers present in the path. Because if the router doesn't have energy to transmit the data, then it will create the data loss through the MPLS-MANET. The router that has high residual energy is preferred for transmitting the data over the network.

4.2.1.4. Distance

In addition, the distance ($Dist$) is considered in the fitness function is used to reduce the energy consumption during the data transmission. Because the energy consumption is directly proportional to the amount of distance traversed in data transmission. If the selected path has less distance, then energy consumption will be low.

4.2.1.5. Number of hops

The number of neighbor routers(N_c) considered as final objective in this AODV-BBO methodology. The router with less neighbors are preferred to prolong the lifetime of the network.

The expression for the HSI/fitness value of the BBO is given in the following Eq. (5).

$$HSI = R_e + Dist + N_c \quad (5)$$

The immigration and emigration rate of each species are updated based on the computed HSI values. The emigration rate and immigration rate are computed based on the Eq. (1) and (2) respectively.

4.2.3. Habitat migration and mutation

In migration process, two different habitats are selected based on the high emigration rate and high immigration rate. In that, habitat (i.e. Path) is updated with remaining habitats position. The habitats are considered in the mutation process based on its mutation probability. This mutation probability is computed based on the emigration and immigration rate that is shown in Eq. (3). The chance of habitat selection for mutation is less when the mutation probability is high. In habitat mutation, the random position is selected and it is mutated by interchanging the router within its same communication range. Additionally, the optimum path is selected based on the best fitness value. The obtained transmission path sends the RREP message to the source router. Then the data packets are transmitted from the source router to the destination router.

The conventional AODV takes more time for creating route table and the increment in network size affects the performance of the network. In order to overcome this, the BBO is integrated into the AODV to overcome the disadvantages of the conventional AODV. The route generation using AODV-BBO methodology considers three fitness function values such as residual energy, distance and number of hops.

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Table 1. Simulation parameters

Parameter	Value
Area	250×250 m^2
Routers	200
Initial energy of router	0.5 J
Number of simulation iterations	300
Communication range from each router	50 nm
E_T	0.2 PJ/bit/ m^2
E_R	0.1 PJ/bit/ m^2
Packet size	4000 bits
Message size	ts

The fitness function considered in this AODV-BBO methodology helps to discover the shortest path from the source route to the destination router. By identifying the shortest path through the MPLS-MANET, the less delay and energy consumption are achieved in AODV-BBO methodology.

5. Results and discussion

The MATLAB R2018a used for implementing the AODV-BBO methodology over i5 desktop computing environment with 8 GB RAM. Here the combination of AODV with BBO is used as the combination to obtain the optimum route over the MPLS-MANET. Since, the optimum route is identified from the source (Ingress router) to the destination (Egress router). The following Table 1 shows the simulation parameters used in the AODV-BBO methodology.

5.1 Performance analysis

The performance of the AODV-BBO methodology is analyzed in terms of alive nodes, dead nodes, energy consumption, bandwidth and end to end delay. This AODV protocol is also simulated for MPLS based MANET with the same specification mentioned in the Table 2. The performance parameters which are analysed in this section are described as follows.

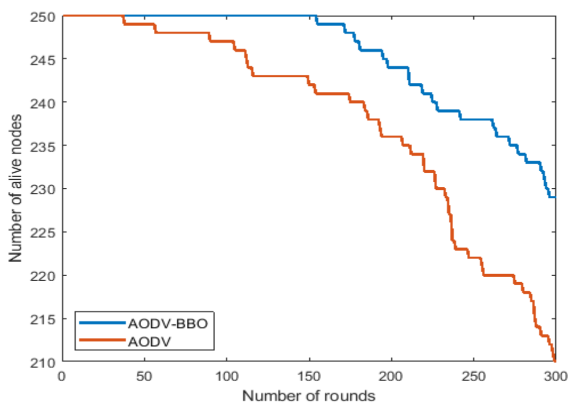

Figure.2 Comparison of alive nodes

5.1.1. Alive nodes

The router which has an adequate amount of energy for transferring the information is named as alive node. An amount of alive nodes becomes high, for an effective data transmission in the network.

The alive nodes comparison of AODV-BBO methodology and AODV routing protocol is shown in the Fig. 2. The alive nodes of the AODV-BBO methodology are high, when compared to the AODV. Because the AODV-BBO methodology considers distance and hop counts during the route generation. The reason behind the AODV with less number of alive nodes is inadequate router selection to create the data transmission path. If the selected router of AODV has a high hop count, it distributes more energy in the data transmission process.

5.1.1.1. Dead nodes

The dead nodes are classified based on the energy of the routers. If the router doesn't have enough energy to transmit the data to other nodes, then it is specified as dead nodes. To ensure the minimum packet loss of the network, the dead nodes present in the network should be less.

$$Dead\ nodes = Total\ number\ of\ routers - number\ of\ alive\ nodes \quad (6)$$

Where, the Eq. (6) is used for determining the number of dead nodes.

The comparison of dead nodes is shown in Fig. 3. The router declares as a dead node when its energy level goes beyond the threshold limit. The dead nodes of the AODV-BBO methodology are less when compared to the AODV.

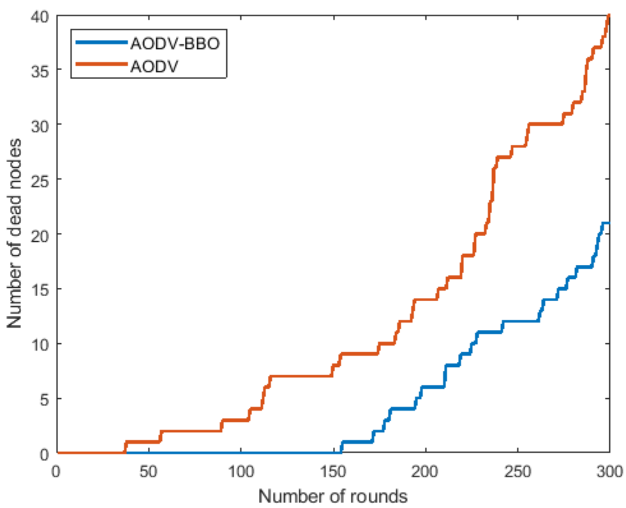

Figure.3 Comparison of dead nodes

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The AODV-BBO methodology achieves less number of dead nodes due to the selection of the router with minimum distance while performing data transmission. Because if the routing protocol selects the router with large distance for data transmission, that router consumes more energy and soon it losses the energy through the network.

5.1.1.2. Energy consumption

The total amount of energy required for each router to transmit the message through the path is called as energy consumption. The energy consumption of an entire network is given in Eq. (7).

$$E_c = E - (E_T + E_R) \quad (7)$$

Where, energy consumption of the network is represented as E_c, E is defined as the total amount of energy, the transmitting and receiving energy is represented as E_T and E_R respectively.

The energy consumption comparison of AODV-BBO methodology and AODV are shown in the Fig. 4. From the Fig. 4, its obtained that the energy consumption of the AODV-BBO methodology is less when compared to the AODV. In general, the network is more effective when the entire energy consumption is less. The energy consumption of the AODV-BBO methodology is reduced by considering the distance among the routers and the number of hops in AODV with BBO based routing.

5.1.1.3. Bandwidth

The data transmitted at a particular time is known as the bandwidth. The bandwidth of AODV-BBO methodology is denoted in bits per second or bytes per second.

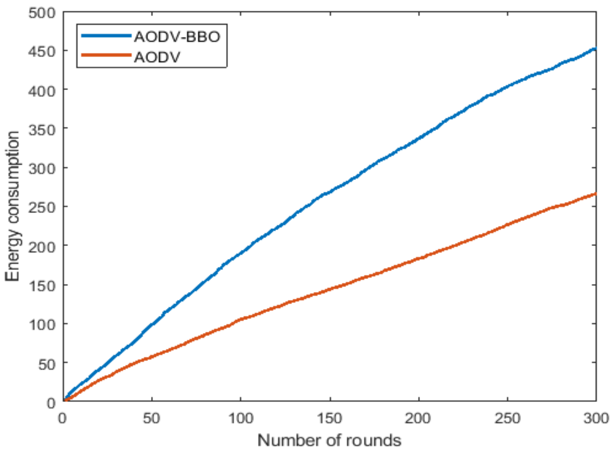

Figure.4 Comparison of energy consumption

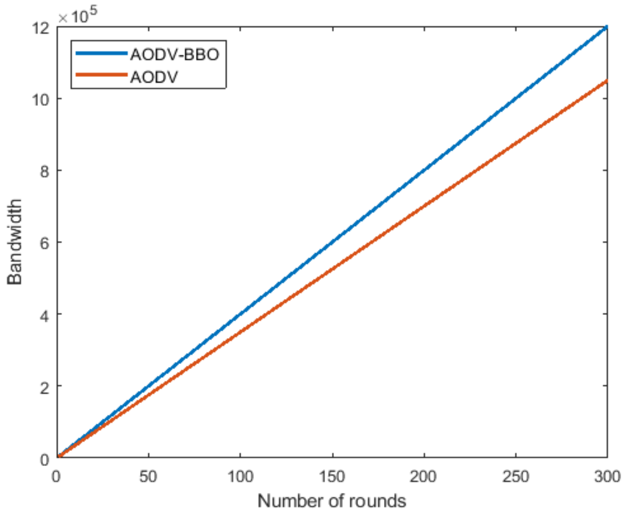

Figure.5 Comparison of bandwidth

The bandwidth comparison of AODV-BBO methodology with AODV is shown in Fig. 5. The bandwidth of the AODV-BBO methodology is higher than the AODV routing protocol. The bandwidth of the AODV-BBO methodology is increased by transmitting more packets from the source router to the destination router without any packet losses. The packet losses among the MPLS based MANET is avoided by eliminating the link and router failure in the route generation process. Because it leads to increase the packet drop in the network.

5.1.1.4. End to end delay

The time taken to transmit the data across the network from the ingress router to the egress router is called as end to end delay.

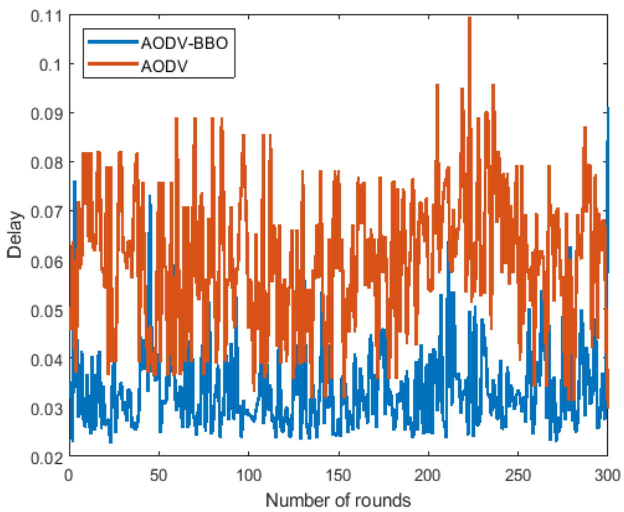

Figure.6 Comparison of end-to-end delay

The end to end delay comparison of the AODV-BBO methodology and AODV are shown in Fig. 6. It shows the end to end delay of the AODV-BBO methodology is less when compared to the AODV routing protocol. The end to end delay of the AODV-BBO methodology is decreased by considering the distance among the routers. Because, the time duration of the data transmission is mainly depending on the distance between the one router to another router.

5.2 Comparative analysis

The efficiency of the AODV-BBO methodology is evaluated by comparing this AODV-BBO methodology with existing methods namely P2R2 method [19] and PS-ROGR technique [20]. Table 2 and Table 3 shows the comparison of AODV-BBO methodology with P2R2 method [19] and PS-ROGR technique [20] respectively. The comparison is made in terms of end to end delay and energy consumption.

The Table 2 shows the end to end delay comparison of the AODV-BBO methodology with P2R2 method [19]. Additionally, the Table 3 shows the energy consumption comparison for PS-ROGR [20] and AODV-BBO methodology. The performance of the Table 2 is taken when the mobility is 20m/s. The performances of Table 3 are taken by varying the nodes from 200 to 500 in the count of 50. This comparative analysis shows that the AODV-BBO methodology has lesser delay than the P2R2 method [19]. Because the performance of the P2R2 method [19] is affected by the node's mobility. Moreover, the energy consumption of AODV-BBO methodology is 452.43J for 250 nodes, it is less when compared to the PS-ROGR [20]. The reason behind the lesser delay and energy consumption of AODV-BBO methodology is the BBO route optimization in AODV.

Table 2. Comparative Analysis of AODV-BBO with P2R2

Simulation time	Delay		Energy consumption	
	P2R2 method [19]	**AODV-BBO methodology**	**P2R2 method [19]**	**AODV-BBO methodology**
15	15ms	0.026ms	-	30.22J
25	17.25 ms	0.0401ms	-	49.68J
35	17.25 ms	0.0257ms	-	67.93J
45	17.25 ms	0.0732ms	-	88.02J

Table 3. Comparative Analysis of AODV-BBO with PS-ROGR

Number of nodes	Delay		Energy consumption	
	PS-ROGR technique [20]	**AODV-BBO methodology**	**PS-ROGR technique [20]**	**AODV-BBO methodology**
200	-	9.79ms	920 J	419.55 J
250	-	10.12ms	962 J	452.43 J
300	-	9.48ms	986 J	474.8 J
350	-	9.74ms	1010 J	497.05 J
400	-	10.47ms	1023 J	536.52 J
450	-	10.707ms	1050 J	548.47 J
500	-	10.47ms	1073 J	554.76 J

This BBO is used to detect the optimal shortest path based on the considered fitness functions such as residual energy, distance and number of hops. Therefore, the AODV-BBO methodology selects the shortest path from the source router to the destination router. The selection of shortest path helps to minimize the energy consumption during data transmission.

6. Conclusion

In this paper, the MPLS is used to handle the dynamic nature of the MANET. The integrated MPLS is used for exchanging the data packets from one router to another router. The optimum transmission path through the routers of MPLS-MANET is obtained by using the combination AODV with BBO. The fitness function considered in the BBO is residual energy, distance and number of hops. Here, the AODV is used to flood the route request messages through the possible paths from the source to the destination. Additionally, the BBO is used to select the optimal path from the discovered paths of AODV. Thus leads to transmission of the route reply message to the source router. Based on this AODV with BBO, the optimum shortest path is created in each and every simulation iteration. The performance of the AODV-BBO methodology is compared with AODV and P2R2 method. From the analysis, conclude that the AODV-BBO methodology gives better performance when compared to the existing methods due to its optimal route selection. For example, the end to end delay of the AODV-BBO methodology is 0.026ms, it is less when compared to the P2R2 method. In the future, an optimization algorithm can be utilized to reduce the energy consumption of the MPLS-MANET.

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