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Performance Enhancement of AODV Routing Protocol for MANET Using Genetic Algorithm

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***Abstract*— Routing in Mobile Ad-hoc Networks (MANETs) has gained gigantic attention due to the mobility of nodes, stand-alone infrastructure, and lack of a centralized arbitrator. These moving nodes make the routing technique highly complex and unstable within a limited radio range. When the network size increases, the length of the complete path increases, and the header size of data packets also increase which brings the network slowdown in operation. To address these issues, many researchers have explored many Artificial Intelligence (AI) techniques to route the data packets from the source to the destination. This paper aims to develop a new routing protocol that exploits the principle of genetic algorithm to find the shortest path from source to the destination. The proposed protocol is experimented through the ns-2 simulator and proves its maximum efficiency over traditional AODV protocol in terms of throughput, average residual energy, and extends the network lifetime at crossover probability 0.5.**

***Index Terms*—MANETs, Routing, AODV, Genetic Algorithm (GA), Fitness Function**

I. INTRODUCTION

Mobile Ad hoc Networks (MANETs) consists of multiple free and self-organized nodes (mobile devices) or some other mobile components interconnected to each other through multi-hop wireless links. In MANETs, as the nodes are mobile, the destination node might be the out of range of a source node while transmitting the data packets. There are a lot of issues in MANETs due to the number of diverse resources such as ambiguity in the line of defense, the operation of nodes in the shared wireless communication medium, dynamic changes in network topology, reliability of the radio link that results in frequent breaking of network connections. Further, there are other factors like scalability issues and mobility of these hosts which can vary depending upon the applications. With the increasing number of portable devices and advanced wireless communication, MANET has gained huge attention with the increasing number of applications like commercial, emergency, Military, battlefield, private sectors, disaster management, etc. So, the development of robust, effective, adaptive, and suitable routing protocols in MANET is very much important to find a suitable path from the source to the destination. Many routing protocols in MANETs have used the concept of on-demand route discovery mechanisms. Some of the popular protocols such as Dynamic Source Routing protocols (DSR), Temporally Ordered Routing Algorithm (TORA), Ad hoc on-demand distance vector (AODV), Location-Aided Routing (LAR), and Zone routing protocol (ZRP) are discussed in the literature [1]. As the proposed protocol is compared with the AODV protocol, we have briefly discussed the working principle of the AODV protocol here.

AODV protocol is the most popular, widely used on-demand routing protocol designed for MANET and provides a base to develop many more new routing protocols. In AODV, if a node wants to broadcast any message, it requests a route to the destination node by sending a route request (RREQ) message to all its neighbors. When any other node receives RREQ message but does not have a route to the destination, that node again broadcasts the RREQ message to all it's neighbors. Also, it keeps a record of reverse-route to the requesting node which can be used to forward subsequent responses for this RREQ message. This process continues until the RREQ reaches a node that has a valid route to the destination. The destination node responds with a route reply (RREP) message after receiving the RREQ message. This RREP is propagated through the reverse-routes of the intermediate nodes until it reaches the original requesting node. At the end of this request-response procedure, a bidirectional path is established between the requesting node and the destination node. When any node loses its connectivity to the next hop, the node terminates its route by sending a route error message (RERR) to all the nodes who had received its RREP.

The main objective of any routing protocol is to maximize packet delivery ratio (PDR), maximize throughput, minimize end to end delay, and maximize the lifetime of the network by consuming less energy. As MANET operates in hazardous environments and emergency areas, there is a requirement to incorporate intelligent machine learning techniques with reliable data delivery mechanisms to handle the dynamics of the networks in an energy constraint environment.

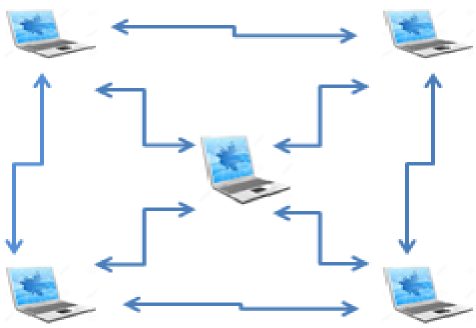

Fig 1: Basic Architecture of MANET

Motivated by this fact, the goal is to explore one of the AI techniques such as genetic algorithm in the AODV protocol to find the shortest path that can produce better performance at varying crossover points. The basic architecture of MANET is shown in Figure 1.

The rest of the paper is organized as follows. Section II discusses the related work based on GA routing for MANET. Section III discusses the proposed heuristic and Simulation results are discussed in Section IV followed by the conclusive remark in Section V.

II. RELATED WORK

This section presents a few existing routing protocols for MANET based on the GA concept. To provide an optimal path in a resource constraint environment (limited battery power and limited bandwidth) is always a challenging task in MANET. So, researchers across the globe have explored different algorithms to provide various solutions to MANET. In [2], the author has discussed the Genetic algorithm to optimize both the distance and congestion factor. The iMASKO framework proposed in [3] has focused on the linear weighted sum cost function to optimize the capacity of the network but it is restricted to population size, the number of generations, etc. A new dynamic AODV backup routing protocol is proposed in [4] that performs very well in a high node mobility situation by creating a backup routing table. The authors in [5] present a GA base perception routing protocol (GABR) to optimize the global available paths that satisfy QoS and perform well over intersection-based routing (IBR) and connectivity aware routing (CAR) in terms of transmission delay and packet loss rate. In [6], an optimal path is suggested in which route stability and energy awareness is focused based on the remaining energy of the node. Similarly, a cognitive mobile agent approach is discussed in [7]. The work in [8] emphasizes on route selection procedure by incorporating GA which satisfies QoS constraints like bandwidth, delay, and node connectivity and proves its efficiency over AODV and DSR protocol. The authors in [9] have presented a smart grid application by using a GA based AODV protocol to find the best path between smart grid sensors to exchange reliable data. The authors in [10] [11] and [14] have emphasized a new objective fitness function by using a linear programming model for path optimization techniques like Ant Colony Optimization and Particle Swarm Optimization, etc. In [12], the authors discuss QoS multicast routing by using a new crossover mechanism called leaf crossover which outperforms existing crossover mechanisms. The work in [13] recommend a Genetic Algorithm fitness function based on delay and hop count for finding a better route to the destination. However, the proposed protocols have failed to consider the sub-optimal routes for route selection in case a route error occurs. The work in [16] presents a fitness function based on the network coverage area keeping in a view of optimal energy consumption. However, this work is limited to WSN applications. In [17], the authors have discussed various mobility models and their impact on routing.

Many researchers have proposed many GA based protocols for MANET and introduced optimal mutation and cross over probabilities for better performance of GA. Each chromosome has its crossover probability P_c and mutation probability P_m necessary to undergo under GA operation. Both P_c and Pm are adapted in proportion to the population to the population maximum and mean fitness during the execution [19]. The cross-over probability is certainly associated with the mutation probability in implementing GA, but the correlation is not substantial [20]. Each protocol has its advantages and disadvantages. Based on the survey, we tried to incorporate GA with variable crossover probability to find out the shortest path that results in good throughput, consumes less energy, and extends the network lifetime at a particular crossover point which is discussed in the next section.

III. PROPOSED HEURISTIC

The proposed model considers an environment consisting of N number of mobile nodes capable of communicating with each other within a radio communication range. Each node carries a unique identification number. All these nodes are self-organized by nature and capable of transmitting and receiving the packets from each other. In our proposed work, 8 mobile nodes are considered initially. Route computation has been done based on the principle of a distributed system. We have applied the Genetic Algorithm concept to find a suitable path from source to destination. Part of the proposed work is reflected in [15] and [18]. This paper aims to enhance the previous research work and tries to find an optimal path from source to destination by varying the crossover probability with a new fitness function.

Terminologies used in Proposed GA-based AODV Protocol

- **Encoding**: Decimal encoding is used.
- **Gene**: It is identified by a string of adjacent nodes
- **Chromosome**: It represents a complete path from source to destination.
- **Offspring**: An adjacent node representing a child
- **Initial Population**: All possible paths from source to destination are created as a set of chromosomes.

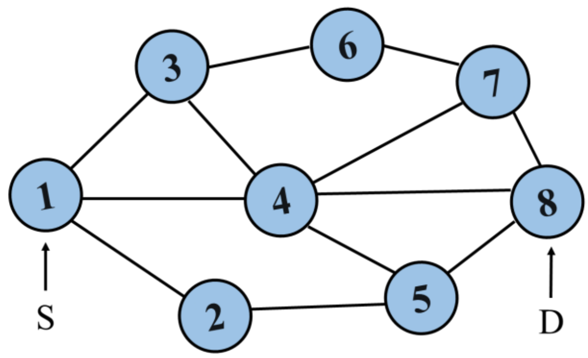

Fig. 2: Proposed Model

Description of Proposed GA-based AODV Protocol

1. The network is considered as homogeneous such as all the nodes have equal initial energy of 1000 Joules.
2. Assume N number of nodes in a network (It is considered 8 nodes initially).
3. The mobile nodes are set with mobility factors so that the distance between the nodes gets changed while routes are being explored.

Problem Formulation

- *Creation of Initial Population:* The initial population is created based on the proposed topology as shown in Fig. 2. The procedure is as follows:
- Initial population/ Initial chromosome through link no 3
  1. 1-3-6-7-8
  2. 1-3-4-7-8
  3. 1-3-4-8
  4. 1-3-4-5-8

  Initial population/ Initial chromosome through link no 4
  5. 1-4-7-8
  6. 1-4-8
  7. 1-4-5-8

  Initial population/ Initial chromosome through link no 2
  8. 1-2-5-8
  9. 1-2-5-4-8
  10. 1-25-4-7-8
- *Calculation of Fitness Function*

In this work, we have considered the link quality to calculate the fitness function along with the node's remaining energy and distance which is discussed in [15]. During the simulation, it is found that signal quality has much more impact on routing a data packet to its nearest neighbor. So, we included signal quality along with energy and distance to calculate the fitness function. If the signal quality is very poor between two nodes, a sending node cannot forward the packet to the receiving node. The new fitness function is given in equation 1. We have used different crossover points to find the desired path from source to destination.

$$F_t = F_r + F_d + F_{RSS} \quad (1)$$

Where,

F_t = Fitness function of each node based on residual energy, distance, and signal quality of a link

F_r = Fitness function related to residual energy is discussed in equation 2.

F_d = Fitness function related to distance is discussed in equation 3.

F_{RSS} = Fitness function related to the received signal strength is discussed in equation 4.

$$F_r = \frac{E_r}{E_t} \quad (2)$$

E_r = Remaining Energy of each node

E_t = Total Energy of all nodes

$$F_d = \frac{S_n - D_n}{D_t} \quad (3)$$

S_n = Represents the sending node

D_n = Represents the receiving node

$S_n\_D_n$= Represents the distance from the source node to destination node

D_t = Total distance from the source to destination considering all the possible paths.

$$F_{RSS} = \frac{S_l}{S_{max}} \quad (4)$$

S_l = Signal strength of a link

S_{max} = Maximum signal strength of a link

The neighbor node is selected by using the proposed Fitness function given in equation 1.

- Crossover and Mutation operation

Crossover and Mutation operations are performed on the chromosomes created by the network topology given in the above section (Initial Population) to find out the new path from source to destination based on the fitness function. After performing crossover, if the path finds a direct link in the proposed topology, then that path is considered to send the data packet. Otherwise, the path is discarded. The black vertical line indicates the cross over point. **N-Path** indicates a new path after the crossover operation.

Example 1: **Case 1:** Chromosome 1 and 5

Cr. 1 1- 3 | -6-7-8 **N-Path-** 1-3-7-8 (ignore-no direct link
Cr. 5. 1- 4 | -7-8 1-4-6-7-8 (ignore-no direct link)

Case 2: Chromosome 1 and 6

Cr 1. 1-3 | -6-7-8 1-3-8 (ignore-if no direct link)
Cr 6. 1-4 | -8 1-4-6-7-8 (ignore-if no direct link)

Case 3: Chromosome 1 and 7

Cr 1. 1- 3 | -6-7-8 1-3-5-8 (ignore-if no direct link)
Cr 7. 1- 4 | -5-8 1-4-6-7-8 (ignore-if no direct link)

Case 4: Chromosome 2 and 5
Cr 2. 1-3|-4-7-8 1-3-7-8 (ignore-if no direct link)
Cr 5. 1-4|-7-8 1-4-7-8 (**Direct link available-success path)**

Case 5: Chromosome 2 and 6
Cr. 2. 1-3|- 4-7-8 1-3-8 (ignore-if no direct link)
Cr. 6. 1-4|-8 1-4-7-8 **(Direct link available-success path)**

Case 6: Chromosome 2 and 7
Cr 2. 1-3-|4-7-8 1-3-5-8 (ignore-if no direct link)
Cr.7. 1-4|-5-8 1-4-7-8 (**Direct Link available-success path)**

Similarly, many random chromosomes can be selected, and crossover operation can be performed to select a path in each round. The flow chart of proposed model is shown in Fig. 3. As our fitness function is based on distance, residual energy, and signal quality, we calculated the residual energy in each

Sl No.	Path Links	$F_r = \frac{E_r}{E_t}$
Path 1	1-4-7-8	0.9995+ .9994+0.9994=2.9983
Path 2	1-4-8	0.9995+0.9989= 1.9984
Path 3	1-3-4-8	0.9993+0.9994+0.9992=2.9970

success path. If the signal quality is very poor in a particular link, data packets can not be transmitted in that path. The energy consumption of a complete path in one round is taken from the trace file as given below.

- **Path 1**-1-4-7-8 =0.50J+0.51J+ 0.51J= 1.52J
- **Path 2**- 1-4- 8 = 0.50J+ 1.07J = 1.57J
- **Path 3**- 1-3-4-8 = 0.67J+ 0.51J+0. 72J= 1.9J

The fitness function w.r.t residual energy is calculated as shown in Table I. For example:
The energy consumption between the link 1 to 4 = 0.50J
So, the remaining energy of that link is = 1000J-50J= 999.5 J
Fitness function of that link is = 999.5/ 1000= 0.9995J

Table I: Calculation of fitness function

Accordingly, the fitness function of the complete path is calculated. The path is having more fitness function w.r.t residual energy is treated as the shortest path to transmit the data.

- Mutation

As the mutation rate is very low such as 0.01, the mutation has been discarded.
The process continues until it satisfies the stopping criteria.

- Stopping Criteria

The algorithm when the newly generated population is replaced by the old population completely. In our case when the total energy is depleted.

// Pseudo Code for Proposed Algorithm//

Input Parameters:
- Set of Decimal Encoded Chromosome, S
- Fitness Function input parameters comprising of residual energy E_l, Distance D_l and Link Quality S_l for a given link 1.
- Terminating condition N_{term} based on number of rounds
- Set of Initial Population P
-rate of crossover
-rate of mutation

Output:
The optimal routing path decimal encoded string based on the given input parameters.

Start of GA algorithm
Initialize the parameters.
t← 0
Initialize P_t to random individuals from S
Evaluate the population (using Decimal Encoding and fitness function P_0

Evaluate-Fitness-GA (S, P_t)
While (GA terminating condition N_{term} <> True)
{
Select individuals from Pt for routing path selection procedure.
Recombine individuals and form offspring with one-point crossover operation.
If (random (0,1< rate of mutation)
Mutate individual using uniform mutation operation.
Endif
Evaluate-Fitness-GA (S, modified individuals)
P_{t+1} ← newly created individuals
t←t+1
} End of while loop
Return (superstring of a routing path from best individuals in P_t

End of GA algorithm

Procedure Evaluate-Fitness-GA (S, P)
S – Set of Decimal Encoded Chromosome**,** S
P – Population of individuals
For each individual i ϵ P
{
Generate derived string s(i)
m ← all blocks from S that are not covered by s(i)
s'(i) ← concatenation of s(i) and m
//for updaton in the set S
remove *m* no of blocks from s'(i) with the lowest fitness value.
Generate Fitness of each link based on residual energy, distance, and signal quality of a link.
} End of for loop.

IV. RESULTS AND DISCUSSIONS

A. Experimental Arrangement

For the experimental set up, ns-2.34 Simulator is used as the test bed tool. The required simulation parameters of interest are defined in Table II. We compare the performance of the proposed protocol with traditional AODV protocol under different node density. Initially, the network is established with 8 nodes in the grid area of 960m x1600m. Then, the number of nodes is increased to 25 nodes and then gradually increased to 50 to check the scalability issue.

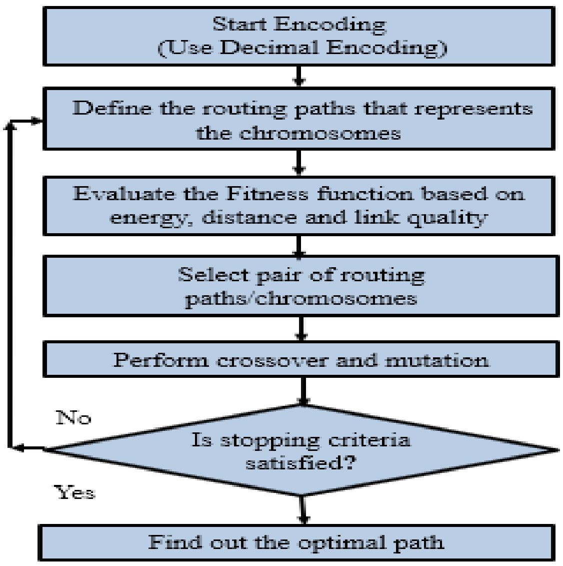

Fig 3. Flow chart for the proposed model

Table II: Simulation Parameters

Parameters	Values
Simulation Area	960m x 1600m
Mobile Nodes	8 to 50
Type of Protocol	AODV
Source of Traffic	CBR using UDP protocol
Antenna Model used	Omnidirectional
MAC protocol type	802.11
Transmission Speed	1.2Mbps
Bandwidth	20Mbps
Total no of data flows	2,13,856 bytes
Security Algorithm	RC5
Payload size	512 bytes
Wireless Channel	Two-way
Simulation Time	350 s
Initial Energy at node	1000 J

B. Results and Discussions

The simulation is carried out over 1900 seconds to check the performance of the proposed protocol. After extensive simulations, the results have been plotted from Fig. 4 to Fig. 8. Various performance parameters such as average residual energy, packet delivery ratio, throughput, and network lifetime are considered and compared with traditional AODV protocol.

The total number of packets transmitted from the source node to the destination is plotted in Fig. 4. It is analyzed and realized that around 68,000 packets are transmitted from the source node in both AODV and GA-AODV protocols. There is not much difference in transmitted packets. The crossover rate is varied from 0.1 to 0.9. A few packets drop occurs during data transmission due to less traffic. Fig. 5 shows the total number of packets delivered to the destination. It is concluded from Fig. 5 that when crossover probability increases, the data delivery ratio increases. But at a certain point, the data delivery ratio drops justifying that crossover and mutation have a huge impact on the output. The experimental results show that at crossover point 0.5, GA-AODV delivers the maximum number of packets at the destination. Figure 6 illustrates that the average residual energy such as remaining energy at each node is more in GA-AODV compared to traditional AODV protocol. Throughput is another parameter to measure the performance of a network. It is defined as the number of packets received at the destination over a unit time as discussed in Equation 5.

$$Throughput = \frac{Received\, data\, packets \times packet size}{Unit\, time} \quad (5)$$

It is also observed from Fig. 7 that the GA-AODV protocol produces better throughput compared to AODV at crossover point 0.5 justifying that a greater number of packets are delivered at the destination per unit time. The network lifetime is determined in terms of the alive nodes. It is observed from Fig. 8 that 50 nodes die around at 1600 sec in AODV protocol whereas the same number of nodes die around 1900 sec in the case of GA-AODV protocol.

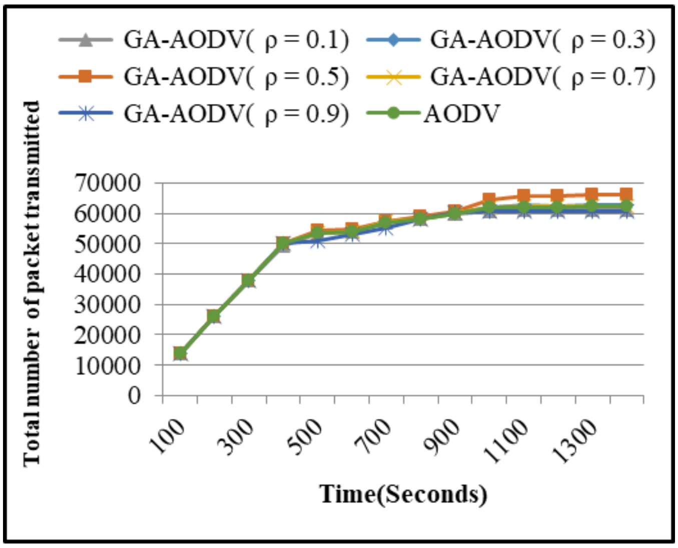

Fig. 4: Total no. of Packets transmitted w.r.t time

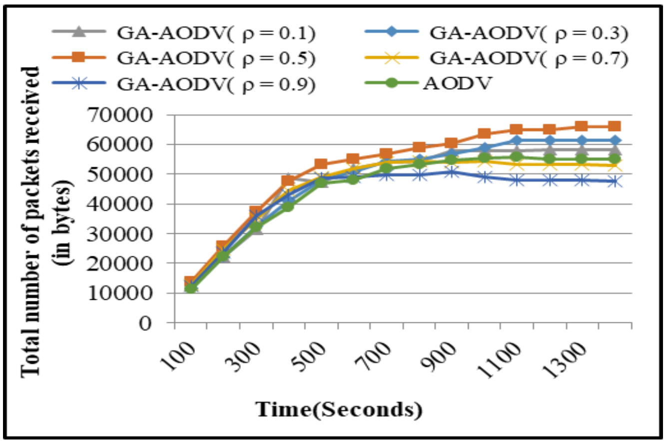

Fig.5: Total no. of Packets received w.r.t time

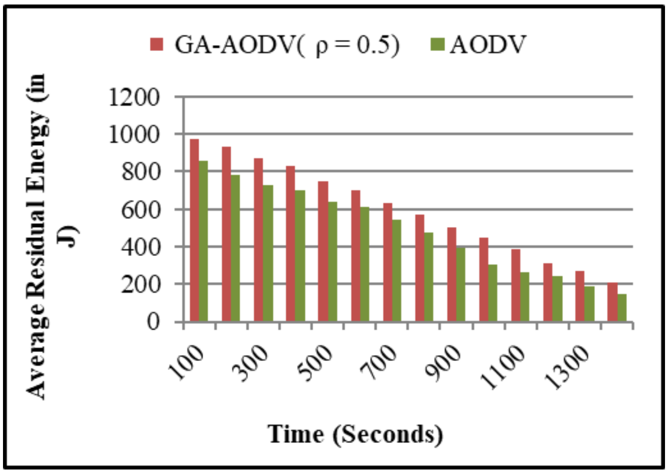

Fig. 6: Average residual energy per node Vs. Time

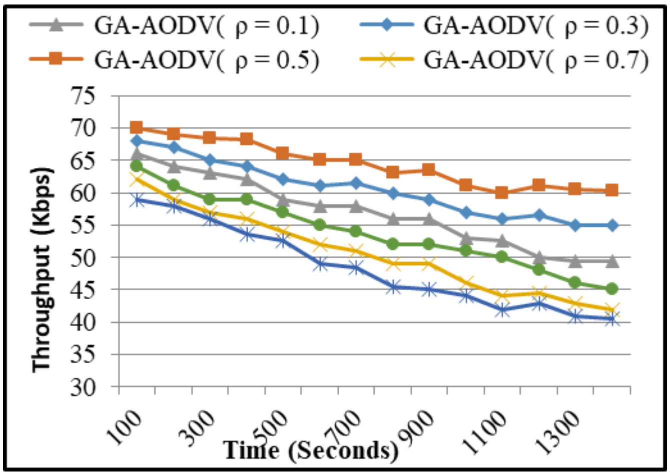

Fig.7:Throughput

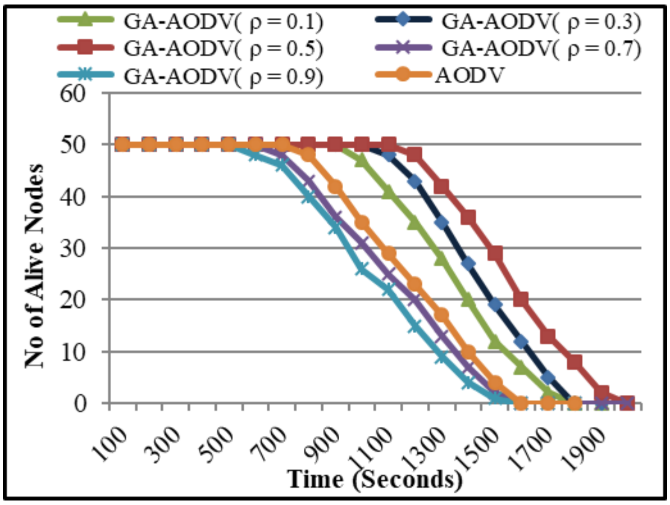

Fig.8: No. of Alive Nodes vs. Time(Network Lifetime)

V. CONCLUSION

This paper presents a novel Genetic Algorithm based AODV protocol in Mobile Ad-hoc Networks to find out the shortest path from the source node to the destination. Furthermore, the proposed protocol finds an alternative path to avoid route discovery in case of node failure or link failure. As the proposed protocol is implemented based on the principle of the Genetic Algorithm, it is experimented and simulated using ns-2 simulator at various crossover points to find out a shortest path from the source node to the destination. The crossover probability is varied from 0.1 to 0.9. The simulation results show that the proposed Genetic Algorithm based AODV protocol outperforms the traditional AODV protocol in terms of various performance parameters such as throughput, average residual energy, and extends the network lifetime. Furthermore, it is observed from the experimental analysis that the optimal performance of GA-AODV occurs at the cross over probability 0.5. The further extension to this proposed algorithm can be to save power at the nodes by using an existing or developing a power aware algorithm. The future work may also include a packet transmission which can be encrypted and hence will enhance the overall security of the MANET.

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