ACODeRA: A Novel ACO Based on Demand Routing Algorithm for Routing in Mobile Ad Hoc Networks

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Abstract

In Mobile Ad Hoc Networks, nodes do not have fixed infrastructure, sufficient storage, energy to operate for longer hours and radio transmission range to communicate among nodes for far off distances. Also, traditional routing protocols fail or do not provide desired quality of services needed for users in the area of deployment of these nodes. These limitations have created challenging issues for researchers. A number of routing protocols are being proposed, but they either fail during real time implementation or their performance parameters degrade. In recent years, Swarm Intelligence (SI) based, more specially Ant Colony Optimization (ACO) based routing algorithms are being proposed by researchers. Each one is based on different characteristics and properties of the ants. It has proved to be better solution for routing problems in MANETs. In this paper, we propose an ACO routing algorithms named ACODeRA for routing in MANETs. We simulate the proposed algorithm using NS-2 and compare the result with traditional AODV routing protocol. The proposed ACODeRA is multi-path routing algorithm and improves the performance parameters such as packet delivery factor. Also, we compare end to end delay for AODV and ACODeRA. The proposed ACODeRA performs better for routing in Mobile Ad Hoc Networks.

Keywords: Swarm Intelligence (SI), Ant Colony Optimization (ACO), AODV, ACODeRA, MANETs.
1. INTRODUCTION

Mobile Ad Hoc Networks (MANETs) [1, 2] are built up of a collection of mobile nodes which have no fixed infrastructure. The nodes communicate through wireless network and there is no central control for the nodes in the network. Routing is the task of directing data packets from a source node i.e. transmitter to a given destination node i.e. receiver. This task is particularly complex due to the dynamic topology, limited process and storing capability, bandwidth constraints, high bit error rate and lack of the central control. It is very challenging for the researchers and engineers to develop and implement a routing algorithm to accomplish the task of routing in changing topology of Mobile Ad Hoc Networks. Ants routing resembles basic mechanisms from distributed Swarm Intelligence (SI) in biological systems and turns out to become an appealing solution when routing becomes a crucial problem in a complex network scenario, where traditional routing techniques either fail completely or at least face intractable complexity. Ants based routing is gaining more popularity because of its adaptive and dynamic nature [3,6,7].

A number of Swarm Intelligence (SI) based, more specially Ant Colony Optimization (ACO) [8-14] based routing algorithms are proposed by researchers. It is a novel evolutionary algorithm, which has the characteristics such as positive feedback, negative feedback, multiple interactions, stigmergy, distributing computing and the use of a constructive heuristic etc. ACOs features, match the demands of network optimization, and a number of ant based algorithms are proposed by researchers.

In this paper a new ant-based algorithm named ACODeRA is presented that combines many features AODV and DSR, DSDV [4,5, 38-40]. This routing algorithm has features to establish multiple routes from source to destination and updates table as per local and global updates available. It reduces the route discovery time and hence able to manage the network topology change very effectively. Further, this paper is organized as follows: Section 2 describes Swarm Intelligence in detail; Section 3 describes Ant Colony Optimization. Section 4 provides detailed description of Ant Routing Algorithms. Section 5 of this paper describes experimental setup and simulation parameters. Section 6 is presented with performance metrics and result analysis with graphs. Section 7 presents conclusion and future scope.

2. SWARM INTELLIGENCE [15-20]

Swarm Intelligence, another novel branch of Artificial Intelligence, has attracted several researchers to apply SI based optimization techniques in solving varied problems of Robotics, Networking, Wireless Communications, Drones, Electronics, Information Theory and other diverse areas. Swarm Intelligence concept was first introduced by Gerardo Beni and Jing Wang [24] in 1989 with relation to cellular robotic systems.

In general terms, Swarm Intelligence [17, 18, 19, 22, 23] is modeling of collective behaviors of simple agents interacting locally among themselves, and their environment, which leads to the evolution of a coherent functional global pattern.
These models are inspired by social behavior of insects and other animals. Talking in terms of computation, Swarm Intelligence models are computing algorithm models used for undertaking and solving complex distributed optimization problems. The basic principle of Swarm Intelligence primarily focuses on “Probabilistic-based Search Algorithms”. In Swarm Intelligence, the most significant concept is “Swarm”. Swarm is used to refer any restrained collection of interacting agents or individuals. Communication among these swarms in distributed manner without any requirement of centralized control mechanism makes these models highly realistic and robust to be implemented in diverse applications.

The concept of Swarm Intelligence was started by two main Algorithms: Ant Colony Optimization (ACO) being developed by Dorigo and Stutzle in 2004 and Particle Swarm Optimization (PSO) being developed by Kennedy and Eberhart in 2001. With time, various other algorithms have come up and make the Swarm Intelligence more rich and implementable in different applications like Fish Swarm, Monkey Swarm, Glowworms, Bee Colony, Artificial Immune System, Firefly Algorithm and many more.

Swarm Intelligence primarily works on two founding principles: 1. Self Organization, 2. Stigmergy

Self-Organization: The concept of Self Organization was defined by Bonabeau et al [27] [28] in 1999 as “Self Organization is a set of Dynamic Mechanisms whereby structures appear at the global level of a system from interactions of its lower-level components”. Self organization lays the foundation of three important characteristics: Structure, Multi-Stability and State Transition.

Structure: It is founded from a homogeneous start-up state. E.g. Ant Foraging trails.


State Transitions: Change of System Behavior. Example: Location of new food source after finishing the entire food transmit from source to nest.

Stigmergy: The word “Stigmergy” is mix of two words: Stigma= Work and Ergon=Work which means Simulation by work. It is based on the principle that the main area to operate for swarms in Environment and work is not dependent on specific agents.

It can be summarized as, “Coordination, Cooperation and Regulation of tasks doesn’t depend on workers directly, but on construction themselves”. The worker is properly guided rather than directed to perform the work. It is also a special form of stimulation called Stigmergy.

Stigmergy can be of following types:

- Sign-Based Stigmergy: Ant Foraging Behavior; Ants Trail Following from nest to food source and vice versa.
- Sematactonics: Building of nests by Termites.
Quantitative: Ants Foraging Behavior
Qualitative: Nest building by Wasps.

For modeling the behaviors of Swarms, Millonas [29] laid the following 4 Principles as follows:

- Proximity Principle of Swarm: Swarms should be highly capable to perform simple computations with respect to the environment existing around them in terms of time and space. E.g. Search for living place and building nest in coordination.
- Quality Principle of Swarm: Swarm should be highly respondent to environmental quality factors like food, safety and other stuff.
- Diverse Response Principle of Swam: The swarm should not allocate all of its resources along excessively narrow channels and it should distribute resources into many nodes.
- Stability and Adaptability Principle of Swarm: Swarms are expected to adapt environmental fluctuations without rapidly changing modes since mode changing involves tremendous amounts of energy.

3. **Ant Colony Optimization [30-37]**

Ant Colony Optimization (ACO) was discovered and introduced by M.Dorigo and colleagues as a Nature-Inspired meta-heuristic for providing optimal solutions to hard combinatorial optimization (CO) problems. A Meta heuristic is regarded as set of algorithms that can be used to elaborate heuristic method applicable to wide range of problems. It is regarded as general purpose framework to different optimization problems with few modifications. “Marco Dorigo” in his Ph.D Thesis “Optimization, Learning and Natural Algorithms”, in which he elaborated the way to solve problems using behavior being used by real ants, presents the first Algorithm defining the framework in 1991. Real Ants are highly sophisticated and intelligent swarms to find the shortest path from food source to nest by depositing pheromone on the ground and laying the trails so that other ants can follow. The most important component of ACO Algorithms is the combination of a priori information regarding the structure with a posteriori information about the structure of previously obtained optimal solutions.

In order to determine the shortest path, a moving ant lay the pheromone which acts as base for other ants to follow and deciding the high probability to follow it. As a result, it leads to the emergence of collective behavior and forms a positive feedback loop system through which other ants can follow the path and makes the pheromone more stable and best path for transferring the food back to nest.

**Combinatorial Optimization Problem- Definition**

The first step for the application of ACO to a combinatorial optimization problem (COP) consists in defining a model of the COP as a triplet \( (S, \Omega, f) \), where:

- \( S \) is a search space defined over a finite set of discrete decision variables;
\( \Omega \) is a set of constraints among the variables; and

\( f : S \rightarrow R^+_0 \) is an objective function to be minimized (as maximizing over \( f \) is the same as minimizing over \(-f\), every COP can be described as a minimization problem).

The search space \( S \) is defined as follows. A set of discrete variables \( X_i, i = 1, \ldots, n \), with values \( v_{ji} \in D_i = \{ v_{1i}, \ldots, v_{|D_i|i} \} \), is given. Elements of \( S \) are full assignments, that is, assignments in which each variable \( X_i \) has a value \( v_{ji} \) assigned from its domain \( D_i \). The set of feasible solutions \( S_\Omega \) is given by the elements of \( S \) that satisfy all the constraints in the set \( \Omega \).

A solution \( s^* \in S_\Omega \) is called a global optimum if and only if

\[ f(s^*) \leq f(s) \quad \forall s \in S_\Omega. \]

The set of all globally optimal solutions is denoted by \( S^*_\Omega \subseteq S_\Omega \). Solving a COP requires finding at least one \( s^* \in S^*_\Omega \).

\[ \text{input: An instance } P \text{ of a CO problem model } \mathcal{P} = (\mathcal{S}, f, \Omega). \]

\[ \text{InitializePheromoneValues}(\mathcal{T}) \]

\[ s_{bs} \leftarrow \text{NULL} \]

while termination conditions not met do

\[ \mathcal{S}_{iter} \leftarrow \emptyset \]

for \( j = 1, \ldots, n_a \) do

\[ s \leftarrow \text{ConstructSolution}(\mathcal{T}) \]

if \( s \) is a valid solution then

\[ s \leftarrow \text{LocalSearch}(s) \quad \text{(optional)} \]

if \( f(s) < f(s_{bs}) \) or \( s_{bs} = \text{NULL} \) then \( s_{bs} \leftarrow s \)

\[ \mathcal{S}_{iter} \leftarrow \mathcal{S}_{iter} \cup \{ s \} \]

end if

end for

\[ \text{ApplyPheromoneUpdate}(\mathcal{T}, \mathcal{S}_{iter}, s_{bs}) \]

end while

\[ \text{output: The best-so-far solution } s_{bs} \]

**ACO for Travelling Salesman Problem (TSP)** [32]

Ant Algorithms are developed on population based approach are applied to combat various NP-hard combinatorial optimization problems. It was the first ACO algorithm, known as “ANT System” [34] [35]. Ant System was applied to Travelling salesman problem (TSP).

The TSP comprise of group of cities connected to each other and distance between them is also known. The objective is to attain the shortest path which facilitates to
visit every city at least once. In order words, to calculate Hamiltonian type coverage of minimal distance between cities on a fully connected graph.

TSP plays vital role in ACO algorithms because of the following reasons:

- Easily applied to ACO algorithms as ants have same kind of behavior to determine the efficient path from nest to source by laying pheromone trails randomly and then choosing the best path for other ants to follow.
- Regarded as NP-hard problem.
- It is a standard testing platform for new algorithms to be checked out and a good performance on TSP is taken into consideration as proof for their correctness and efficiency.
- TSP being the first combinatorial problem, that was solved by ant algorithms.

**ACO Algorithm applied to TSP**

Procedure ACO algorithm for TSPs

1. Define parameters, initialize pheromone trails
2. While (termination condition not met) do
   - ConstructSolutions
   - ApplyLocalSearch %optional
   - UpdateTrails
3. end
end ACO algorithm for TSPs

**Ant Colony Optimization-Definition**

Ant Colony Optimization technique is based on ants i.e. how ant colonies find the efficient path between nest and food source. In search of food, ants roam randomly in the environment. On location of the food source, ant’s first return back to their nest by laying a trail of chemical substance called “Pheromone” in their path. Pheromone lays the foundation for communication medium for other ants to follow the way and go to the food source. When other ants follow the path, the quantity of pheromone increases on that particular path. The rich the quantity of pheromone along the path, the more likely is that other ants will detect and follow the path. In other words, ants follow that path which is marked by strongest pheromone quantity. As pheromone evaporates over time, which in turn reduces its attractive strength? The longer the time taken by ant to travel the path from food source to nest, the quicker the pheromone will evaporate. So, the path should be shorter so that the active strength of pheromone is maintained and ants can easily transfer the food from source to nest. So, in turn of this policy the shortest path will naturally emerge.
ACODeRA: A Novel ACO Based on Demand Routing Algorithm for Routing.

The following algorithm explains Ant Colony Optimization:

Initialize Parameters
Initialize pheromone trails
Create ants

**While** stopping criteria is not reached, **do**

Let all ants construct their solution
Update pheromone trails
Allow Daemon Actions

**End while**

**Suitability of Ant Colony Optimization Routing Algorithm**

Ant Colony Optimization Routing Algorithm mentioned above is highly suitable and performs well for the following reasons: Provide traffic adaptive and multipath routing. Rely on both passive and active information monitoring and gathering. Making use of stochastic components. Don’t allow local estimates to have global impact. Setup paths in a less selfish way than in pure shortest path schemes favoring load balancing. Showing limited sensitivity to parameter settings

4. **DESCRIPTION OF ANT ROUTING ALGORITHMS** [37]

Mobile Ad Hoc Network with V nodes connecting with E links are represented by weighted digraph as:

\[ G = (V, E) \]

In the proposed Ant Based on Demand Routing Algorithm ACODeRA, two ants are used. One FANT, which is created at Source S and moves to destination D. The other is BANT, which is created at Destination and follows the part of FANT and updates the route table. The FANT available at node i, follows the path through node j by probability formulae:

\[ P(i, j) = \frac{\rho(i, j)}{\sum_{s \in Ni} \rho(i, s)} \text{ if } s \in Ni \quad (1) \]

\[ = 0 \text{ otherwise.} \]

Where, Ni is neighbor node set of node i.

\( \rho (i, j) \) is pheromone strength on link e (i, j)
\[
\sum_{se\in E} P(i, j) = 1 \quad (2)
\]

When forward ant FANT moves on link \(e(i, j)\) then \(\rho(i, j)\) is updated by formule:
\[
\rho(i, j) \leftarrow (1 - q)\rho(i, j) + \Delta \rho(i, j) \quad (3)
\]

And
\[
\Delta \rho(i, j) = \frac{\alpha}{D(i, j)} \quad (4)
\]

where \(\Delta \rho(i, j)\) is increment of pheromone by FANT.

\(\alpha\) is tunable parameter and utilized to calculate allowed delay \(D(i, j)\) and \(q \in (0, 1)\) is pheromone evaporation parameter.

When FANT reaches to Destination \(D\), it is destroyed and BANT is created and routed through the path of FANT. During this process, pheromone parameter \(\rho(i, j)\) is again updated by formule:
\[
\rho(i, j) \leftarrow (1 - q)\rho(i, j) + \Delta \rho(i, j) \quad \text{If}(i, j) \in R
\]
\[
\rho(i, j) \leftarrow (1 - q)\rho(i, j) \quad \text{Otherwise} \quad (5)
\]

\(R\) is reverse route, which FANT passes from source to destination.

\[
\Delta \rho(i, j) = \beta \min \{ B(i, j) \} \quad (6)
\]

\(\beta\) is tunable parameter used to influence bandwidth \(B(i, j)\), \(\min B(i, j)\) is minimum bandwidth of the link to maintained the desired quality of service.

Now we can define the probabilities \(P1\) and \(P2\), of two paths through mobile nodes \(i\) and \(j\), from same source \(S\) to same destination \(D\) as:

\(P1= (S, i_1, i_2, i_3, \ldots, i_m, D)\) and \(P2= (S, j_1, j_2, j_3, \ldots, j_m, D)\)

Let us consider, intermediate node sets are

\(I = \{ i_m | 1 \leq m \leq |V| \}\) and \(J = \{ j_n | 1 \leq n \leq |V| \}\)

If \(I \cap J = \Phi\) then \(P1\) and \(P2\) are two similar routes.

**Route Discovery** - When node \(S\) sends a packet to destination node \(D\). Node searches the destination route in the routing table. If it is not available in the routing table, it creates a FANT with source address and broadcasts to all adjacent nodes.

I. When an intermediate node \(i\) receives the FANT and checks destination address of FANT, if destination address is not same: (a) node \(i\) adds own address and time FANT arrived to \(i\), (b) node \(i\) adds the source address as destination address for routing BANT, into routing table and computes pheromone value according to formule
shown above (c) the bandwidth is considered for the link between nodes. (d) Hop count is also updated. (e) node i broadcasts FANT to neighbor again, if did not receive the route of destination.

II. When node i receives duplicate FANT i.e with same sequence number and source address, the above steps are followed. If sequence number is less than or equal to max sequence number and route record of FANT includes address of present node, then the FANT is discarded. Otherwise node updates the max sequence number by new value and executes the steps shown in I.

III. When destination of FANT is same as that of i, route is discovered. FANT is discarded after retrieving relevant information from FANT, and BANT is sent on to the path followed by FANT. Again the pheromone table is updated as per BANT equation defined above. When BANT reaches to the source S all the pheromone tables are updated.

**Route Maintenance** – When there is congestion at node i, node i will retrace the path of FANT to inform to source S to change route. Pheromone value is changed from source and same value is updated in routing table, so that congested path is not further loaded. When all the routes fail, source S will initiate a new route request again. When there is error in the node, mainly due to change in location of mobile node. The pheromone value is made to 0, so that route is not followed by the broadcasting node.

**Basic Ant Colony Routing Algorithm- Flowchart**

The following diagram shows the Flowchart- showing the flow of Ant Colony Routing Algorithm.

![Flowchart showing the Working of Ant Colony Routing Protocol](image)

**Fig. 1 Flowchart showing the Working of Ant Colony Routing Protocol**
5. EXPERIMENTAL SETUP AND RESULTS

The Network Simulator NS-2 experimental setup is used for performance evaluation of the AODV and ACODeRA routing protocols. It measures the ability of protocols to adapt to the dynamic network topology changes while continuing to successfully deliver data packets from source to their destination. In order to measure this ability, different scenarios are generated by varying the pause time of nodes. We use following scenario generation commands for generating scenario file for 50 nodes:

```
./setdest -v 1 -n 50 -p 10.0 -M 10.0 -t 1000 -x 1500 -y 300;
./setdest -v 1 -n 50 -p 20.0 -M 10.0 -t 1000 -x 1500 -y 300;
./setdest -v 1 -n 50 -p 30.0 -M 10.0 -t 1000 -x 1500 -y 300;
./setdest -v 1 -n 50 -p 40.0 -M 10.0 -t 1000 -x 1500 -y 300;
./setdest -v 1 -n 50 -p 50.0 -M 10.0 -t 1000 -x 1500 -y 300;
```

Similarly, for connection pattern generation we use, cbrgen.tcl file. By using command

```
“ns cbrgen.tcl -type cbr -nn 50 -seed 1.0 -mc 16 -rate 4.0;”
```

the connection pattern is generated.

The trace file is created by each run and is analyzed using a variety of scripts, particularly one called file *.tr that counts the number of successfully delivered packets and the length of the paths taken by the packets, as well as additional information about the internal functioning of each scripts executed. This trace file is further analyzed with AWK file and Microsoft Excel is used to produce the graphs.

In order to measure the performance of proposed Ant Based on Demand Routing Algorithm ACODeRA effectively, we compare the performance of ACODeRA with AODV for varying pause time. Nodes we have considered are 50 and they move within an area of 1500m x 300 m using Random Waypoint Model. The maximum speed of nodes we have considered in simulation is 10m/s. The channel capacity is 2 Mbps and transmission range of each node is taken as 250m. Traffic Type is 20 CBR (continuous bit rate) traffic sources each send 4 packets per second with a packet size of 64 bytes. Packet Delivery Fraction and End to End Delay is considered as evaluation parameter for this simulation. Also, we have considered nodes with Omni-Antenna and Two Ray Ground Radio Propagation method. Simulation parameters are appended in Table-1.
**Table: 1. Simulation Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulator</td>
<td>NS-2.34</td>
</tr>
<tr>
<td>Protocols studied</td>
<td>AODV and ACODeRA</td>
</tr>
<tr>
<td>Simulation time</td>
<td>25,50,75,100 sec</td>
</tr>
<tr>
<td>Simulation area</td>
<td>1500 X 300</td>
</tr>
<tr>
<td>Transmission range</td>
<td>250 m</td>
</tr>
<tr>
<td>Node movement model</td>
<td>Random Way Point</td>
</tr>
<tr>
<td>Traffic type</td>
<td>CBR (UDP)</td>
</tr>
<tr>
<td>Data payload</td>
<td>64 Bytes / packet</td>
</tr>
</tbody>
</table>

6. PERFORMANCE METRICS AND RESULT ANALYSIS

In this paper we have considered End to End Delay in milli second and Packet Delivery Fraction (PDF) in percentage for evaluation of AODV and ACODeRA routing protocols.

6.1 Packet Delivery Fraction (PDF).

It is the ratio of the data packets delivered to the destination to those generated by the sources.

Packet Delivery Fraction (PDF) = Total Packets Delivered to destination / Total Packets Generated.

Mathematically, it can be expressed as:

\[
P = \frac{1}{C} \sum_{f=1}^{C} \frac{R_f}{N_f}
\]

Where, \( P \) is the fraction of successfully delivered packets, \( C \) is the total number of flow or connections, \( f \) is the unique flow id serving as index, \( R_f \) is the count of packets received from flow \( f \) and \( N_f \) is the count of packets transmitted to \( f \). The Packet Delivery Fraction with varying pause time for AODV and ACODeRA is calculated. The comparison between AODV and ACODeRA are placed in table 2 and 3 and graphs are shown in fig. 2 and fig. 3.
Table 2. Packet Delivery Fraction with varying Simulation Time

<table>
<thead>
<tr>
<th>Simulation Time</th>
<th>AODV</th>
<th>ACODeRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>85.41121</td>
<td>89.93382</td>
</tr>
<tr>
<td>50</td>
<td>82.9991</td>
<td>90.27102</td>
</tr>
<tr>
<td>75</td>
<td>80.13186</td>
<td>88.60818</td>
</tr>
<tr>
<td>100</td>
<td>77.23998</td>
<td>86.43871</td>
</tr>
</tbody>
</table>

Fig.2: Packet Delivery Fraction with varying Simulation Time

Table 3. Packet Delivery Fraction with varying Pause Time

<table>
<thead>
<tr>
<th>Pause Time</th>
<th>AODV</th>
<th>ACODeRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>84.4112</td>
<td>92.9338</td>
</tr>
<tr>
<td>20</td>
<td>81.9991</td>
<td>92.271</td>
</tr>
<tr>
<td>30</td>
<td>79.587</td>
<td>91.6082</td>
</tr>
<tr>
<td>40</td>
<td>77.1749</td>
<td>90.9454</td>
</tr>
<tr>
<td>50</td>
<td>74.7626</td>
<td>90.2826</td>
</tr>
</tbody>
</table>
6.2 End to End Delay:

It includes buffering delay, queuing delay, propagation delay, retransmission delay and transfer delay. The multi-path route of ACODeRA can select path by the bandwidth of the path in the route. As a result, the buffering delay and the retransmission delay are decreased. The End to End Delay with varying simulation time and varying pause time for AODV and ACODeRA are calculated. The comparison between AODV and ACODeRA is carried out and data obtained in appended in table 4 and 5. The graphical presentation is shown in fig.4 and fig.5.

<table>
<thead>
<tr>
<th>Simulation Time</th>
<th>AODV</th>
<th>ACODeRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>3.42</td>
<td>3.02</td>
</tr>
<tr>
<td>50</td>
<td>5.11</td>
<td>4.33</td>
</tr>
<tr>
<td>75</td>
<td>6.91</td>
<td>5.76</td>
</tr>
<tr>
<td>100</td>
<td>8.71</td>
<td>7.19</td>
</tr>
</tbody>
</table>
Fig. 4: End to End Delay with varying Simulation Time

Table 5: End to End Delay with varying Pause Time

<table>
<thead>
<tr>
<th>Pause Time</th>
<th>AODV</th>
<th>ACODeRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>5.95</td>
<td>2.13</td>
</tr>
<tr>
<td>20</td>
<td>6.03</td>
<td>3.02</td>
</tr>
<tr>
<td>30</td>
<td>6.92</td>
<td>3.56</td>
</tr>
<tr>
<td>40</td>
<td>6.99</td>
<td>4.33</td>
</tr>
<tr>
<td>50</td>
<td>7.36</td>
<td>5.05</td>
</tr>
</tbody>
</table>

Fig. 5: End to End Delay with varying Pause Time
7. CONCLUSION

In this paper, we have evaluated the performance of ACO based, named as Ant Based-on-Demand Routing Algorithm ACODeRA with traditional routing protocol AODV for Mobile Ad Hoc Networks using NS-2 event simulator. The proposed ACODeRA decreases the average end-to-end delay and the times of congestion happening effectively by on demand creating the multiple routes of link disjoint paths. This is because the proposed algorithm uses local updating rule and global updating rule to update the pheromone of link and the probability route table. Also, selects route and balances traffic flows considering bandwidth and probability from routing table. Experimental results show that ACODeRA performs better in both the performance matrices i.e. for Packet Delivery Fraction as well as End to End delay with varying simulation time and pause time.

It has been found that the overall performance of proposed ACO based ACODeRA routing protocol for performance matrices, Packet Delivery Fraction as well as End to End delay is better than that of traditional AODV routing protocol. In our experimental evaluation, we have taken up comparison of ACODeRA and AODV protocols with varying simulation time and pause time with fixed number of nodes to 50.

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