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Cluster Based Ant Colony Optimization Routing For Vehicular Ad Hoc Networks

S. Balaji[1], S. Sureshkumar[2], G.Saravanan[3]
[1,2]*M.E Computer Science and Engineering, P.A. College of Engineering and Technology, Pollachi*
[1]*sbalajiccie@gmail.com* ,[2]*sureshsmartthinker@gmail.com*
[3]*Assistant Professor, P.A. College of Engineering and Technology, Pollachi*

Abstract - Vehicular Ad hoc Networks (VANET) are offset of Mobile Ad hoc Networks (MANET) made by vehicles communicating with each other. The special characteristic of VANET is high speed of nodes, so the time period of network is very small. Performing routing operation in such high dynamic network environment is difficult process. This work proposes cluster based Ant Colony Optimization routing in VANET scenario. In flat architecture each node bear equal responsibility, so that routing is performed in deployed cluster architecture. In first phase deploy a cluster architecture followed by Ant Colony Optimization routing procedures that results in a DYMO variant protocol called as ACO-DYMO routing protocol, that perform well in dynamic network, has it performance evaluated in urban scenario. The obtained results suggest that making use of Ant Colony optimization Procedures in Cluster architecture is more suitable for Vehicular Ad hoc Networks.

1 INTRODUCTION

Vehicular Ad hoc Networks are special type of mobile Ad hoc Networks, made by vehicles communicating with each other and with devices located in road. The device installed in vehicles is called as On Board Units and device located in margin of roads are called Road side units. In vehicle to vehicle communication each On Board Unit work in ad hoc mode and forward message through multiple hops, but in this scenario network connectivity is highly depended on vehicle's density and mobility pattern.

VANETs are offset of MANETs and they have some distinguished characteristics too. The main characteristic of VANET is high speed of nodes (vehicles), so that the topology is highly dynamic and network is formed for very small amount of time that directly impact packet delivery. The solutions proposed for MANETs need to be evaluated carefully and then adapted in VANET environment. The goal of this work is to device and evaluates bio-inspired procedures in a deployed architecture.

2 RELATED WORK

Ant-Colony Based Routing Algorithm (ARA) [9] is a reactive MANET routing protocol that uses the ACO metaheuristic [2]. ARA's artificial pheromone model is probabilistic and based on the number of hops. Through a search procedure, a forward ant (FANT) will create a pheromone trail from the source to the destination. A backward ant (BANT) does the same in reverse path, i.e. after a FANT reaches its destination, it is destroyed and a BANT is created and it is sent back to the source node, and finds its way to the destination by the means of a procedure similar to that of the FANT. It then creates the pheromone trail, or if it already exists, it increases the pheromone level on the path. The data packets also enforce the pheromone level on the path they are passing through.

Ant On-Demand Distance Vector Routing (Ant-AODV) [15] is a hybrid routing algorithm for MANETs based upon AODV, without changing any of AODV's native characteristics. AODV does the reactive part and an ant-based approach does the proactive one. The main goal of the ant algorithm here is to continuously create routes in the attempt to reduce the end-to-end delay and the network latency, increasing the probability of finding routes more quickly, when required. Ant-AODV's artificial pheromone model is based on the number of hops and its goal is to discover the network topology, without any other specific functions, as opposed to most ACO algorithms [6].

Ant Dynamic Source Routing (Ant-DSR) [1] is a reactive protocol that implements a proactive route optimization method through the constant verification of cached routes. This approach increases the probability of a given cached route express the network reality.

Mobility Aware Ant Colony Optimization for VANETs [22] devised ACO procedures that results in bio-inspired protocol called as MAR-DYMO and results obtained are evaluated in urban VANET scenario. In regard to end-to-end delay, it performed much better than pure DYMO protocol, and was good enough when compared to the hybrid protocol Ant-DYMO. The obtained results inspired to use those procedures in deployed architecture.

Harri, Bonnet and Filali devised a location-aware frame work called Kinetic Graphs [11] for predicting and managing mobility. It assumes that, over a short period of time, an arbitrary node i will be following a linear trajectory, and hence its position can be modeled as a function of time by the means of 1st order kinetics, as shown in Equation (1).

$$Pos_i(t) = \begin{bmatrix} x_i + v_{xi}.t \\ y_i + v_{yi}.t \end{bmatrix} \quad (1)$$

Pos_i (t) is the position of the node i at time t, the vector $[x_i; y_i]^T$ denotes the initial position of the node i, and the vector

[v_{xi} ; v_{yi}], its instantaneous velocity. This work, will apply the Kinetic Graphs framework to make information such as the vehicles' position and speed available to the routing protocol, so that it will be able to use it for making its forwarding decision, aiming at a better overall routing performance.

3 Autonomous Clustering

3.1 Overview

The autonomous clustering [18] divides the network into multiple virtual groups to efficiently manage the network. Each cluster contains one clusterhead, two or more clustermembers and gateways. Gateways are nodes that are neighbor to other clusters. Each node has unique node ID and node ID of the clusterhead is assigned to the cluster as cluster ID. Multiple clusters that are configured by autonomous clustering are not overlapped with each other.

3.2 Formation of Cluster

In autonomous clustering by default all nodes that are not part of any cluster will be in ON (Orphan Node) state. ON nodes periodically broadcast a MEP (Member Packet) that contains its own node ID to inform its existence to neighbouring nodes. Each node that received the MEP adds the source node of MEP to its list of neighboring nodes. If all states of neighboring nodes are ON, the node sets its own cluster ID to its cluster ID, and becomes clusterhead. As a result, clusters are formed.

3.3 Management of Cluster

Clusterhead in a cluster periodically broadcast a MEP that contains its ID within the cluster. Clustermembers that receive MEP send MAP (Member Acknowledge Packet) containing its information back to clusterhead. The clusterhead construct cluster-based tree and creates list of Clustermembers to manage the cluster. The size of each cluster is restricted with upper bound U and lower bound L in advance. If number of cluster members become more than U, then cluster is divided into two, on the other hand if cluster members become lower than L, it merges the cluster with neighboring cluster.

4 Proposed Scheme- Cluster Based Ant Colony Optimization Routing for VANET

4.1 Overview

In flat architecture of every node bears equal responsibility to act as a router for routing packets to every other node, so a great amount of message flooding takes place in order to obtain better routing efficiency. In return, such message flooding reduces the MAC layer efficiency to a certain extent. Clustering can be one possible solution to improve such MAC layer efficiency and makes the routing process easier [24]. Followed by autonomous clustering [18][22], Ant Colony Optimization procedures are employed for routing process.

4.2 Ant- Colony Optimization Procedure

The major component of ACO algorithm is pheromone model [5] with two most important mechanisms: the way pheromones get deposited in the path ants pass through and the way pheromones evaporate[23]. These mechanisms will be discussed in following subsections.

4.3 Pheromone deposit

As like traditional ant the level of pheromone on a path indicates how good the path is, it reflects the quality of path, its cost. Consider the link l_{ij}, an ant walking from node *i* to node *j* deposits an amount of pheromone on the path. When the ant reaches node *j* in routing table entry of *j*, *i* is added as both destination and next hop, is increased of $\Delta\phi ij$. Figure 1 shows the pheromone table of the node j after receiving an ant from the neighbor node *i*.

$\Delta\phi_{ij}$ is defined as being the amount of pheromone to be deposited in the route for the link l_{ij}, and it will sum up with the previous pheromone level (assuming that route already existed), if it is a newly acquired route then, it is just be the actual level, it is represented in equation (2).

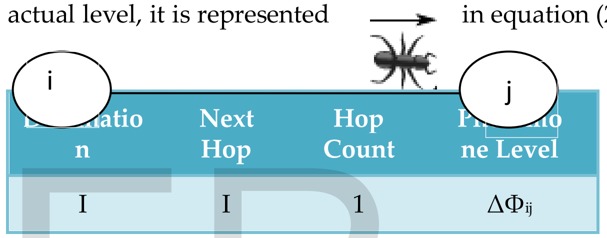

Figure 1. Ant walking through the link l_{ij}. The routing table at j is shown after the ant reaches j, and illustrates the pheromone deposit process

$$\Delta\varphi_{ij} = P_r + \frac{T_{min}}{T_{max}} \quad (2)$$

P_r is the expected probability of successfully receiving message sent through given distance, d meters, i.e., the probability of *j* receiving a message form node *i* or vice versa. T_{min} is the route lifetime, given by the Kinetic Graphs framework, and T_{max} is a value defined as the maximum route lifetime. The upper bound T_{max} is specified to avoid larger route lifetime.

From [13], we have that for Nakagami distribution with a positive integer value for the fading parameter m, we obtain

$$P_r(d, CR) = e^{-m(d/CR)^2} \sum_{i=1}^{m} \frac{\left(m(d/CR)^2\right)^{i-1}}{(i-1)!} \quad (3)$$

Equation (3) gives the probability of successfully receiving a message sent through a distance d between the sender and receiver in an intended communication range CR. Equation (3) does not consider the effects interference. Our pheromone deposit equation then becomes

$$\Delta\phi ij = e^{-m\left(d_{ij}/CR\right)^2} \sum_{i=1}^{m} \frac{\left(m(d/CR)^2\right)^{i-1}}{(i-1)!} + \frac{T_{min}}{T_{max}} \quad (4)$$

Equation (4) will determine the amount of pheromone to be deposited in every link visited by the ants, which will be the probability of reception of a message through this path summed with the ratio between the lifetime estimation of that path and the maximum (upper bound) lifetime. The probability of reception indicates the path quality. For multi-hop routes whose length is bigger than the transmission range, the only indicative of quality is the estimated lifetime for the path.

4.1 Evaporation Process

Just like real ants, an ACO algorithm simulates the evaporation process of pheromone trails left by the ants while traveling through the link.

From a practical standpoint, the evaporation process is necessary to avoid a too fast algorithm convergence towards a suboptimal region; it is a way to escape from a local optimum [5].

From an implementation standpoint, periodically every t_{ev} seconds, the pheromone level of all links decrease following a mathematical model that tries to imitate the evaporation mechanism of the real ants. Equation (5) show evaporation mechanism

$$\varphi \leftarrow (1-\rho).\varphi \quad (5)$$

ϱ is the so-called pheromone evaporation rate and ϕ, the pheromone level associated with that path.

In several ACO algorithms, such as ARA [9], ARAMA [12] and Ant-DYMO [14], to name a few, the evaporation rate ϱ is fixed and the same for all links, usually a value found in some empirical way. The work propose different evaporation rates for every link, based on the assumption they are actually different, and hence, should behave differently in regard the pheromone evaporation.

Through Kinetic Graphs, we have now estimation on the duration of a path, which will be represented by T_{min}, from Equation (2). In practice, the route will be removed after T_{max} seconds and it become invalid.

Now proceed to calculate the rate needed to evaporate a link within T_{min} seconds. Let $\varphi^{[k]}$ represent the pheromone level of an arbitrary link after the evaporation process described by Equation (5) is performed k times.

Hence,

$$\varphi^{[k]} = \varphi.(1-\rho)^k \quad (6)$$

Equation (6) shows the amount of pheromone associated with this link after it suffers the evaporation process k times.

Let ϵ be a smallest amount (different of zero) of pheromone possible to be associated with a link, for which we assume the following:

$$\varphi = \begin{cases} \varphi, & if\ \varphi \geq \epsilon \\ 0, & otherwise \end{cases} \quad (7)$$

Therefore,

$$\varphi.(1-\rho)^k = \epsilon$$

$$\rho = 1 - \left(\frac{\epsilon}{\emptyset}\right)^{\frac{1}{k}} \quad (8)$$

As the evaporation mechanism is performed after every t_{ev} seconds, k value is calculated, that tells the number of times the evaporation process was performed:

$$k = \frac{T_{min}}{t_{ev}} \quad (9)$$

By combining (9) with (8), we get the evaporation rate a given link will be subject to, so that it will completely evaporate after its predicted duration:

$$\rho = 1 - \left(\frac{\emptyset}{\rho}\right)^{\frac{t_{ev}}{T_{min}}} \quad (10)$$

5 Application of the Proposed Techniques To An Existing DYMO Routing Protocol

In this section, application of the proposed techniques presented in the previous section to the DYMO [3] routing protocol is done, and obtain the Ant Colony Optimization Routing DYMO, or simply ACO-DYMO, for short.

5.1 Ant Colony Optimization Routing DYMO (ACO-DYMO

As DYMO is a reactive protocol. DYMO is going to turn it into an ACO algorithm by adding the pheromone deposit and pheromone evaporation discussed in section III. First we start by modifying the HELLO message from the DYMO protocol to add the fields shown in Figure 2.

← 32 bit →

position (vector)	displacement (vector)	
speed (vector)	scalar speed	timestamp

Figure 2. Data a vehicle needs to transmit in order to allow others to make predictions on its mobility

Now HELLO messages are not periodic anymore, but they will be sent by the vehicles when needed, in an aperiodic fashion managed by the Kinetic Graphs framework. That way the nodes will keep a table with updated info on their neighbors. This information allows a vehicle to make predictions on their neighbors, such as their position at a given time instant and the time they will be still neighbors, for instance.

For turning the DYMO protocol into an ACO algorithm, the routing table is adapted to carry, for each route the pheromone level associated with the link and evaporation rate calculated through equation (10) and they are changed to work in a multi-path fashion too, so that actual route will be chosen among the existing routes based on corresponding pheromone levels, by using the roulette-wheel selection method. Route with a higher pheromone level will have higher probability of being chosen.

$$p_i = \frac{\emptyset_i}{\sum_{j=1}^{N} \emptyset_j} \quad (11)$$

Equation (11) shows the probability a route i to a given destination will be chosen, among N (multiple) routes for the same destination.

6 Performance Evaluation

6.1 Simulation

The simulations are carried out using the network Simulator 2.34[16],[4], with modules Mac 802.11 Ext and WirelessPhy-Ext, based on original ns-2 wireless modules. Propagation of signals Nakagami radio propagation model is used.

Table I

SUMMARY OF THE SIMULATION PARAMETERS

Simulation parameters	
Simulation area	1600mX1500m
Communication range	350m
Propagation Model	Nakagami
Mobility Model	Gipps
Application	VBR
Transport	UDP
MAC and PHY	802.11

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Packet size	512 bytes
Transmission range	300,400,500,600, 700,800,900,1000
Interface Queue	20 packets
Simulation Time	150 Seconds
Number of Vehicles	100
Routing Protocols	AODV,ACO-DYMO

The vehicular traffic is generated by the Vehicular Network Moment generator [17] according to lane changing behavior proposed by Gipps [7], belong to the class of collision avoidance vehicular mobility models. The AODV protocol is compared against the developed ACO-DYMO. The simulation parameters are summarized in Table 1.

1) Scenario: The scenario is a 1600mX1500m urban area. The roads have two lanes each and the vehicular traffic flows in both directions.
2) Data Traffic: The traffic used in the simulations is UDP. During the whole simulation, each node will be sending data to a random destination for a time chosen between 10 and 60 seconds. Data rate varies from 250 to 1000. At regular intervals parameters are monitored. 3) Metrics: Four metrics are considered in order to evaluate the routing protocols in the proposed scenario: – the average delivery ratio, the average end-to-end delay, routing overhead and throughput. The average delivery ratio is defined as being the number of packets successfully received at the destinations per number of packets sent by the data traffic sources. This metric tells how good was the protocol in the task of successfully transmitting data end-to-end.

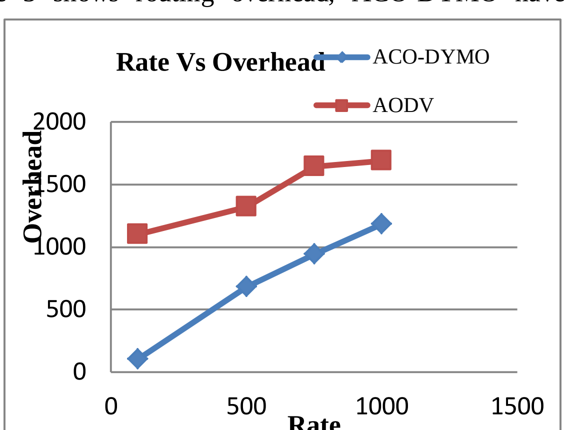
The average end-to-end delay is defined as being the average of the sum of the time it took to send/receive each of the successfully delivered packets and it tells about the latency of the protocol.

Throughput is the average rate of successful message delivery over a communication channel. This data may be delivered over a physical or logical link, or pass through a certain network node. The throughput is usually measured in bits per second (bit/s or bps).

The routing overhead is defined as being the number of routing packets – such as the protocol messages – per number of data packets successfully received at the destinations. This metric tells about the extra traffic generated by the routing protocol in order to successfully deliver data packets.

6.1 Result and Discussion

Figure 3 shows routing overhead, ACO-DYMO have less routing overhead when compared to AODV. Figure 4 shows ACO-DYMO have good delivery ratio than AODV. Figure 5 shows average end-to-end delay is reduced in the proposed scenario, and AODV have worst performance.



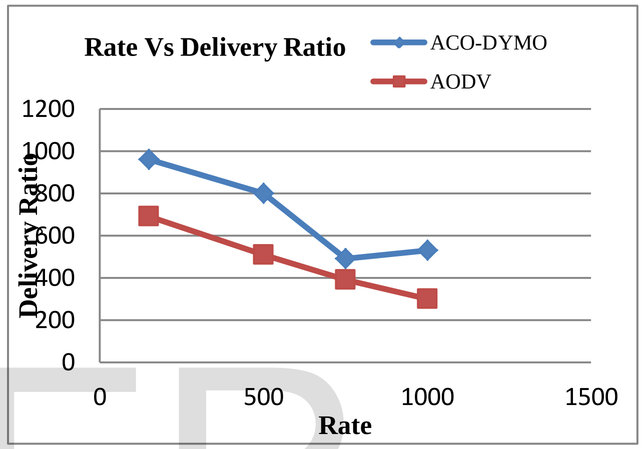


Figure 3. Routing Overhead

Figure 4. Average Delivery Ratio

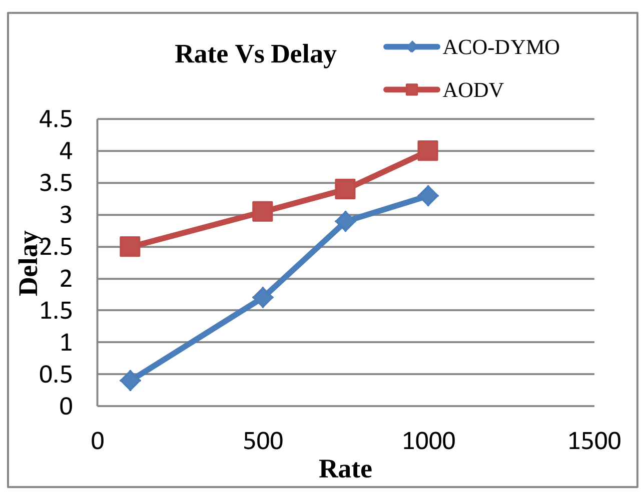


Figure 5. Average Delay

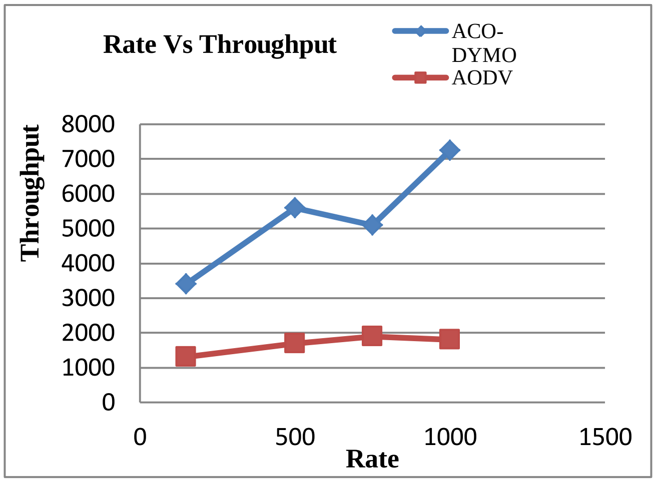


Figure 6. Throughput

Regarding throughput the proposed ACO-DYMO perform much better than AODV, showed in Figure 6

7 Conclusion

The paper had introduced a combined approach of clustering architecture and Ant Colony Optimization (ACO) routing procedures. The proposed method had worked pretty well in urban VANET scenario compared to AODV protocol. This paper concentrated only reactive phase routing, in future work proactive phase routing will be employed with Ant Colony Optimization procedures.

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