Routing Algorithm for Vehicular Ad Hoc Network Based on Dynamic Ant Colony Optimization

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***Abstract*—Increasing interests in Vehicular Ad hoc networks over the last decade have led to huge investments. VANET (Vehicular Ad-hoc Network) is a new field of technology which has been widely used in autonomous systems. Due to rapid topology changing and frequent disconnection makes it difficult to design an efficient routing protocol. Various routing protocols for VANETs have been recently proposed. Most approaches ignored parameters which effect performance of real VANET applications like environmental changes. Environmental changes can affect both performance and throughput in VANET. In this paper, we proposed a routing algorithm based on ant colony optimization and DYMO (Dynamic MANET On-demand) protocol which copes with changes in environment. Ant colony optimization algorithm is a probabilistic technique which has been widely used in finding routes through graphs. Two parameters were considered to evaluate discovered paths in this paper: (i) delay time, (ii) path reliability. Ns-2 was used to implement the proposed algorithm and monitor its performance through different amount of modifications in environment. Results proved that the proposed ant colony routing algorithm can achieve better performance in compare of other well-known methods like Ad Hoc on Demand Distance Vector (AODV).**

***Index Terms*—VANET, ant colony optimization, routing algorithm, DYMO**

I. Introduction

VANET is a special type of mobile ad hoc networks (MANETs). It has some characteristics similar to those of MANETs, such as self-organization, self-management and short-range radio transmission. In addition to these similar characteristics, a VANET also has some unique characteristics, such as highly dynamic topology, sufficient energy capacity and predictable mobility model. The network architecture of VANET can be classified into three categories:

- Pure cellular/WLAN
- Pure ad hoc
- Hybrid [1].

There are many research projects around the world which are related with VANET such as COMCAR [2], PRE-DRIVE C2X [3], FleetNet [4] and NoW (Network on Wheels) [5], CarTALK 2000 [6], CarNet [7]. There are several VANET applications such as Vehicle collision warning, Security distance warning, Driver assistance, Cooperative driving.

In a VANET, communication occurs from vehicle to vehicle (V2V) or from vehicle to infrastructure (V2I). A vehicle needs to transmit its data to other vehicles or roadside units to provide a variety of applications, such as traffic control, environment monitoring, and inter-vehicle communication. For this purpose, a path needs to be established between a source and its destination or roadside unit before data transmission, and routing therefore becomes a critical issue in the design of a VANET.

Routing problem is one of major issues in VANETs. Routing is in conjunction with the admission, flow and congestion control components, determines the overall network performance in terms of both quality and quantity of delivered service.

A variety of routing algorithms have been proposed in the literature, which can be classified into five categories:

- Ad hoc routing
- Position-Based routing
- Cluster-Based routing
- Broadcasting
- Geocast routing [8]

Routing algorithms can also be classified as minimal or non-minimal. Minimal routing allows packets to follow only minimal cost paths, while non-minimal routing allows more flexibility in choosing the path by utilizing other heuristics. Minimal routing can further be subdivided into optimal routing and shortest-path routing.

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II. Related Works

A variety of routing protocols have recently been proposed for different network scenarios, such as AODV (Ad-hoc On-demand Distance Vector) [9] and DSR (Dynamic Source Routing) [10], which were originally proposed for MANETs but can also be used for VANETs with lower throughput [11]. Moreover, GPSR (Greedy Perimeter Stateless Routing) [12] is a well-known routing protocol proposed particularly for VANETs, which can achieve a better performance than AODV and DSR in a suburban scenario. GPCR (Greedy Perimeter Coordinator Routing) [13] is another routing protocol proposed particularly for VANETs, which is based on GPSR and does not use any street map. Although these routing protocols have been proposed for VANETs, all of them have this or that limitation in achieving network performance or addressing different network scenarios.

Temporally Ordered Routing Protocol [14] is based on the link reversal algorithm that creates a direct acyclic graph towards the destination where source node acts as a root of the tree. In TORA packet is broadcasted by sending node, by receiving the packet neighbor nodes rebroadcast the packet based on the DAG if it is the sending node's downward link.

Vehicle-Assisted Data Delivery [15] focused on multihop data delivery through vehicular ad hoc networks which is a complicated problem. The method is based on the idea of carry & forward approach by using predicable vehicle mobility.

Huang, *et al.* [16] studied movement characteristics of vehicle nodes in VANET and proposed a GPSR based routing algorithm. Also this paper considered circle changing trends angle in vehicle speed fluctuation curve and the movement domain

MEDAL [17] is a routing algorithm for both vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communications in VANETs. MEDAL takes advantage of both the moving directions of vehicles and the destination location to select a neighbor vehicle as the next hop for forwarding data.

Metaheuristic algorithms are another approach which has been widely used in routing problem. Ant colony optimization [18] is a metaheuristic algorithm which is inspired by the behavior of a real ant colony.

AntNet [19] is a novel approach to the adaptive learning of routing tables in communications networks. AntNet is a distributed, mobile agents based on Monte Carlo systems.

Correia, *et al.* [20] proposed Ant Colony Optimization (ACO) algorithm which uses information available in vehicular networks such as the vehicles' position and speed in order to design an ant based algorithm that performs well in the dynamics of such networks. The authors have also adapted the Dynamic MANET On-demand (DYMO) routing protocol [21] to make use of the ACO procedures.

III. Ant Colony Optimization Algorithm

Bio inspired computing is a major part of natural computation. It takes bottom-up and decentralized approach. Bio-inspired techniques involve the methods of specifying a set of simple rules, a set of simple organisms which follows those rules, and an iterative method applies to those rules [22]. Bio-Inspired Algorithms can be divided into two classes, namely, Evolutionary Algorithms and Swarm based Algorithms which are inspired by the natural evolution and collective behavior in animals respectively.

Swarm Intelligence appears in biological swarms of certain insect species. It gives rise to complex and often intelligent behavior through complex interaction of thousands of autonomous swarm members. Interaction is based on primitive instincts with no supervision. The end result is accomplishment of very complex forms of social behavior and fulfillment of a number of optimization and other tasks. The main principle behind these interactions is called stigmergy, or communication through the environment. An example is pheromone laying on trails followed by ants in ant colony optimization algorithm. Ant colony optimization algorithm is a metaheuristic [18] algorithm which is inspired by foraging behavior of ants. Pheromone is a potent form of hormone that can be sensed by ants as they travel along trails. It attracts ants and therefore ants tend to follow trails that have high pheromone concentrations. Ants attracted by the pheromone will lay more pheromone on the same trail, causing even more ants to be attracted.

Ant colony optimization algorithm has advantages like:

- Scalability: Population of the agents can be adapted according to the network size. Scalability is also promoted by local and distributed agent interactions
- Fault tolerance: Ant colony optimization processes do not rely on a centralized control mechanism. Therefore the loss of a few nodes or links does not result in catastrophic failure, but rather leads to graceful, scalable degradation
- Adaptation: Agents can change, die or reproduce, according to network changes
- Modularity: Agents act independently of other network layers

Fig. 1 shows flowchart of ant colony optimization algorithm.

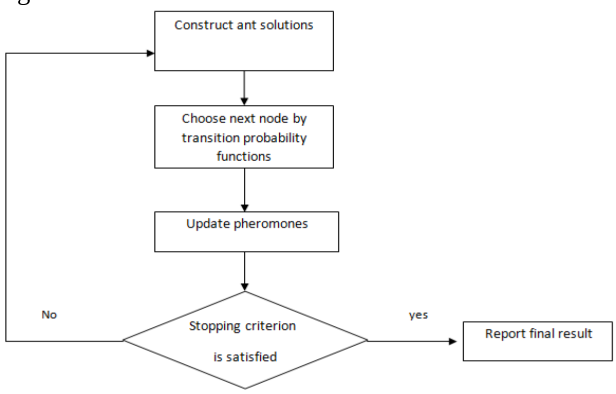

Figure 1. Flowchart of ant colony optimization algorithm

IV. Proposed Algorithm

In this paper, we proposed a routing algorithm in

Vehicular ad hoc networks based on DYMO routing protocol and ant colony optimization algorithm in which it can work efficiently through changeable environments. Environmental changes can cause Modifications in routes, damages in infrastructures and disconnection between nodes (vehicle to vehicle or vehicle to infrastructure).

DYMO [21] is a reactive and unicast routing protocol for multihop wireless networks and is considered a successor of the popular AODV. It consists of two basic operations:

- Route discovery
- Route maintenance

The route discovery procedure is performed when a node in the network wants to send data to another node for which it does not know a route for. At this point, the first node creates a route request (RREQ) message and floods the network with it. The RREQ messages keep a list of visited nodes, so that a node, upon receiving a RREQ message, can update its routing table with a route to the source of this message. After receiving an RREQ message, the node checks whether it has a route to its destination, and if it does, it sends a route reply (RREP) message back to the source of the RREQ, telling it about this route. An RREP is also sent if the receiving node is the actual destination of the RREQ message.

The route maintenance procedure takes care of eliminating invalid routes from routing tables, attributing to each route a duration time. When a route is successfully used in the forwarding of data packets, the lifetime associated with that route is extended. When the route lifetime expires, its associated route is removed from the routing table. In This way, DYMO only keeps routes that are being used frequently.

With considering process of DYMO protocol and iterative procedure of ant colony optimization algorithm, we proposed a new ant based routing algorithm.

Two types of ants are considered in proposed algorithm:

- Explorer ant: responsible for creating routes to its source
- Search ant: responsible for searching for a specific destination

Explorer ants carry the information on the destination node and create pheromone trails along the way. Also they carry the address of the source node and also a list containing every intermediate node it has passed by.

The processing of an ant can be divided in two phase:

- If TTL>0 (TIME TO LIVE) and reliability> β then add the new node address and broadcast explorer ant to neighbors
- Otherwise discard the explorer ant

RREQ format in proposed algorithm is based on DYMO's RREQ which is improved with a probabilistic search mechanism that takes into account the level of pheromones on the paths. The transition probability of the ant located at the node (m) to the node (n) as the next hop is defined by (1).

$$P(m,n) = \begin{cases} \dfrac{\varphi(m,n)}{\sum_{s\in N_i}\varphi(m,s)} & if\ s\in N_i \\ 0 & otherwise \end{cases} \tag{1}$$

In (1), N_i is the set of 1-hop neighbors of node (m) and $\varphi(m, n)$ is the pheromone level on the link $e(m, n)$. Following equations are considered for pheromone update:

$$\varphi(m, n) = \varphi(m, n) + \Delta\varphi(m, n) \tag{2}$$

$$\Delta\varphi(m, n) = \frac{c_1}{Distance\,(m, n)} + (c_2 * etx_v) \tag{3}$$

Two parameters were considered for pheromone update:

- Distance between two nodes which effects delay time
- Path reliability (etx_v): For reliability metric, we used ETX [23] for calculating the path reliability. ETX is defined as the expected number of transmissions (including retransmission) for a successful end-to-end data forwarding and hop-by-hop acknowledgment. The following expression shows how to compute the ETX metric for a path:

$$etx_v = \frac{1}{fd_v + rd_v} \tag{4}$$

fd_v: the forward delivery ratio is the measured probability that a data packet successfully arrives at the recipient

rd_v: the reverse delivery ratio is the probability that the ACK packet is successfully received

c_1 and c_2 are adjustable parameters that represent the influence of the distance and reliability of a path.

Equation (5) models the pheromone evaporation scheme, similar to the real ants, where the pheromone level reduces with time (α is evaporation factor):

$$\varphi(m, n) = (1-\alpha).\ \varphi(m, n) \tag{5}$$

V. EXPERIMENTAL RESULTS

The simulation environment chosen for evaluating proposed algorithm was the ns-2 network simulator [24] in its version 2,34.

DYMOUM [25] was used as basis for implementation of proposed algorithm in ns-2. For more accurate implementation The Nakagami radio propagation model was used as well.

The vehicular traffic was generated by VanetMobiSim [26]. The Vehicular Ad Hoc Networks Mobility Simulator (VanetMobiSim) is an open source, java-based generator of realistic vehicular mobility traces. VanetMobiSim consists of following modules:

- Traffic generator
- Obstacle generator
- Incident Extension: specifies an incident class, its location and its duration in environment

The simulation parameters are summarized in Table I.

Table II shows parameters which were used for implementation of proposed algorithm.

Table III shows result of end to end delay comparison between proposed algorithm and Ad Hoc on Demand Distance Vector (AODV).

TABLE I. SUMMARY OF SIMULATION PARAMETERS

Simulation Parameters	
Scenario Area	500m*500m
Communication range	80m
Propagation model	Nakagami
Transport	UDP
Simulation Time	100 sec
Size of RREQ	176
MAC and PHY	IEEE 802.11

TABLE II. VALUE OF PARAMETERS IN ANT COLONY BASED ROUTING ALGORITHM

Implementation parameters	
Number of Ants	100
Maximum number of iteration	10
Default TTL	7
Receiving signal threshold	30db
Noises caused by environmental changes	40-60db

TABLE III. COMPARISON BETWEEN PROPOSED ALGORITHM AND AODV

Algorithm	Number of vehicles	End to end delay(ms)
Ant colony based algorithm	14	45.21
AODV	14	74.18
Ant colony based algorithm	25	92.33
AODV	25	117.25

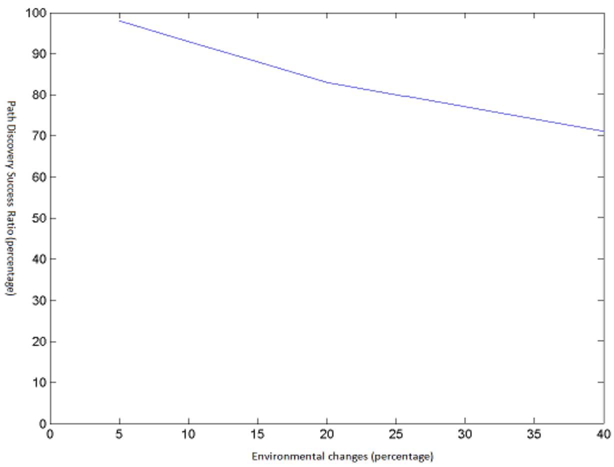

Figure 2. Path discovery success ratio based on environmental changes

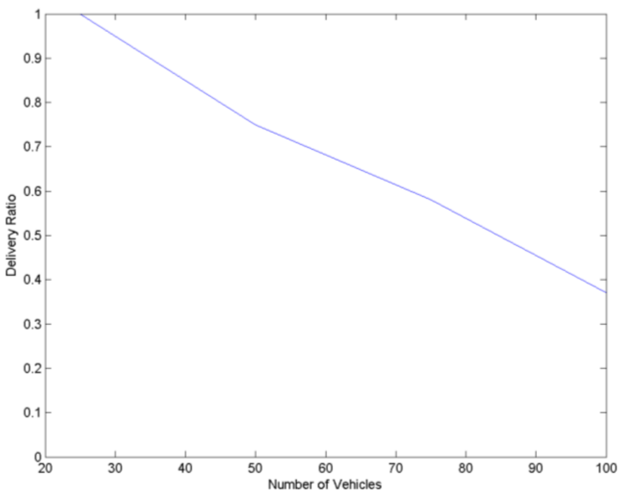

Figure 3. Delivery ratio

Fig. 2 shows path discovery success ratio value according to environmental changes.

Fig. 3 shows delivery ratio according to number of vehicles in proposed ant colony based routing algorithm.

VI. CONCLUSION

In this paper, we studied routing problem in VANET through changeable environments. The proposed routing algorithm is based on ant colony optimization and DYMO protocol. Our goal was proposing a novel algorithm which can cope with noises, disconnection between nodes and damages in infrastructures. Two parameters were considered to evaluate discovered paths in this paper: (i) delay time, (ii) path reliability. The simulation environment chosen for evaluating proposed algorithm was the ns-2 network simulator. The vehicular traffic was generated by VanetMobiSim. A comparison was made between ant colony based routing algorithm and Ad Hoc on Demand Distance Vector (AODV). Following results were observed within experimental analysis:

- Increasing accuracy of path finding with considering changes in environment
- Decreasing Delay time in network
- In compare to AODV, less number of lost and dropt packets was observed

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