

An enhanced routing algorithm using ant colony optimization and VANET infrastructure

Noussaiba Melaouene and Rahal Romadi

Team of information Research and indexing documents, texts and multimedia, ENSIAS, Mohammed V University, Rabat, Morocco

Abstract. For the last fifty years, finding efficient vehicle routes has been studied as a representative logistics problem. In the transportation field, finding the shortest path in a road network is a common problem. VANET presents an innovation opportunity in the transportation field that enables services for intelligent transportation system (ITS) especially communication features. Because of VANET features [1] and despite road obstacles, a route for the shortest path can be established at a given moment. This paper proposes an enhanced algorithm, based on ACO Ant Colony Optimization and related to VANET infrastructure that aims to find the shortest path from the source to destination through the optimal path; in addition, a storage on static nodes is installed in each intersection in a VANET environment and for a specific time.

1. Introduction

A vehicular ad hoc network (VANET) joins features in vehicles in order to make them smarter [1]. Vehicular Communication in VANETs considers two major architectures: Vehicle-to-vehicle communication (V2V) that enables communication between vehicles, and Vehicle-to-infrastructure (V2I) that is the wireless exchange of information between vehicles and roadside. Figure 1 shows a Vehicular Ad Hoc Network characterized by a highly dynamic topology that results in a frequent disconnected network. Thanks to unlimited battery storage, nodes in VANETs do not experience power limitation. To improve the safety of the transportation area, VANETs network enables the development of many applications such as safety applications to avoid accidents, efficiency applications to maximize road capacity and avoid traffic congestion, and commercial applications to access internet.

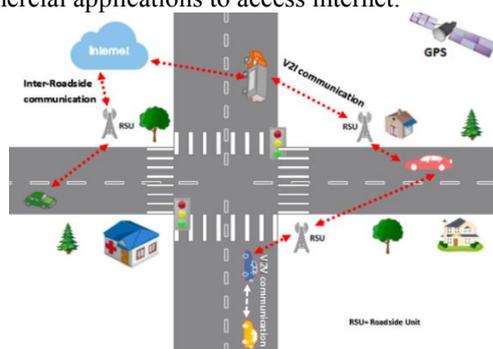


Figure 1. VANET infrastructure

Ants in nature manage amazing feats like building nests and finding food. The swarm intelligence of natural environmental agent called ant colony optimization (ACO) was developed by Dorigo [2, 3] as a kind of meta-heuristic optimization method. The ACO is based on the communication system used by ants when they look for food sources [4]. Ants search food starting from their nest and taking different paths to reach food. In this situation, the only necessary information is the path taken to food. Nevertheless, the complete topology of the environment is that not clear for a single ant which deposits the pheromone along its path. Subsequent ants use an indirect communication, which consists of tracing the pheromone left by the previous ants. The more the ants pass through a particular path, the more the concentration of the pheromone increases along that path. The pheromone acts as significant stimuli since other ants can sense the pheromone deposited by each other, and they generally take the path with maximum pheromone concentration [5]. Ants follow this method to progressively converge on a single optimum path between their nest and food.

Initially, the important goal is to provide the shortest and the most optimal path for a vehicle from source S to its destination D. This can be realized through the swarm intelligence techniques that use behavior similar to the living organisms in nature (explained above). These techniques form a part of artificial intelligence and have a wide range of applications that exists in the literature. Some of these techniques are being used in vehicular networks that implement routing or vehicles behavior control.

In a real VANET network, obstacles between two or more vehicles may exist. These obstacles weaken the

transmitted signal and hinder communication. Therefore, it is necessary to find alternative communication routes for vehicles in these conditions expand it through all Road Side Units (RSU) in routes in a given time for better quality services, increase the waiting time and improve information centralization. To meet this objective, this paper proposes an enhanced algorithm based on Ant Colony Optimization (ACO); a nature-inspired algorithm with fast response time, low computational effort, and that is particularly useful for routing problems.

This paper is organized as follows: section 2 outlines a literature survey of many proposed algorithm for routing problems in VANETs, section 3 presents the proposed work and its main goal, while the detailed steps are explained in section 4. Some assumptions and the method to implement the algorithm are presented in section 5. Section 6 concludes and offers a future outlook.

2. Literature survey

A large number of routing protocols have been proposed for VANETs [6, 7]. The main goal of these routing protocols is to provide the best path through multiple wireless communications. Some ACO-based algorithms for the routing problems in VANETs have been proposed. In this section, most representative literature on vehicular routing areas using ACO algorithm (Ant Colony Optimization) are provided.

R.Silva et al in [8] propose an ACO-based algorithm for multi-objective routing in VANET. The proposed algorithm, called AntRs, find routes considering the best commitment between shortest path (number of nodes/vehicles in a route) and the lowest probability of disconnection. Simulations are implemented in three different scenarios namely static routing, static routing with obstacles, and dynamic routing. Results are very promising showing a good adaptability. Nevertheless, the algorithm still has to be improved to fit high-density and dynamic networks.

G.Caro in [9] describes a hybrid algorithm, named AntHocNet, combining both reactive and proactive elements. After a reactive path setup, the algorithm probes, maintains and improves path in a proactive way. The algorithm is based on the nature-inspired Ant Colony Optimization framework. The advantage exists in terms of packet delivery ratio, average end-to-end delay and average jitter, and increases in larger, sparser and more dynamic environments. However, AntHocNet is less efficient in terms of routing overhead.

Toklu in [10] proposes a robust multiple ant colony system to solve the uncertain travel cost problem. To generate a collection of solutions with different levels of protection against the uncertainty, the author uses multiple ant colonies in parallel; each of which focuses on a different conservativeness degree. This method is handled by incorporating linear formulations from the field of robust optimization into the metaheuristic approach.

G.Li in [11] proposes a new adaptive multi-criteria VANET routing protocol, named VACO (Vehicular routing protocol based on Ant Colony Optimization). The

proposed algorithm combines both reactive and proactive components to respectively establish and maintain best routing paths. The simulations indicate that VACO shows better performance than reference protocols (GPSR and CAR). The algorithm still has to be improved to fit with realistic vehicular traffic.

3. Proposed work

The proposed algorithm aims to provide the best path from source to destination. First, an area with randomly scattered N vehicles is considered. The area contains multiple intersections and obstacles. To reduce the probability of disconnection, the communication features in VANETs are required to establish a connection between vehicles (V2V) and between vehicle and infrastructure (V2I). The route between the source S and the destination D is divided into sub-routes to make research easier and to reduce the waiting time.

At the beginning, the source vehicle S starts by checking if a route already exists in the neighborhood or not. If the answer is affirmative, the vehicle S follows the given routing path. If not, the search of the best path to destination starts using Ant Colony Optimization; this is called the reactive path exploration where the exploration of the path is established on demand. When a *forward ant* arrives to destination D , respecting the less end-to-end delay, a reactive *backward ant* is generated to return to the source S and deposit the pheromone on the optimal road; the deposited pheromone describes the quality of the road. Once the route is established, the optimal route found is recorded and sent to the roadside units at intersections, where the information is updated for a definite time interval. The goal of the information centralization at intersections is to reduce the movement of vehicles individually on the routing path. Finally, a process of pheromone evaporation is necessary in each time interval.

Choosing VANET environment was necessary for its network characteristics. First, the VANET network is homogeneous; vehicles have the same physical capacity and the same radio power [1, 8]. Second, there is no hierarchy between vehicles thus the network can be described as Flat. Finally the dynamic topology of the VANETs network enables communication during movement.

It is important to mention that network congestion is not considered in this paper. The optimal path will be the one with the best commitment between the less end-to-end delay and the lowest hops number between the source and the destination.

4. The algorithm description

In this section, a detailed description of the different components of our proposed algorithm is given.

4.1 The path exploration

The aim of the algorithm is to find the best path from source S to destination D . To do so, N vehicles are

randomly scattered in the area. The source vehicle S sends route request to the two neighboring intersections to check whether a route to destination is already recorded or not. If the route exists and is updated, the intersection sends an affirmative message to S, and then the source vehicle S directly implements data packet forwarding [12]. Otherwise, S starts to search the best path between Source and destination utilizing the Ant Colony Optimization by sending *forward ant*.

At the beginning, the source S sends *ants* randomly to the neighboring intersections searching candidate routing path to destination D. When arriving at intersection I, the task of the *forward ant* is to find the path connecting S to D. At each intersection, according to whether or not the intersection has the routing information to D, an *ant* is either unicast or broadcast. The next intersection j of the forward ant is chosen probabilistically according to equation (1) [8, 13] based on the global pheromone deposited at intersection (i).

$$P_{i,j} = \tau_{i,j} / \sum_{k=1}^n \tau_k \quad (1)$$

where $P_{i,j}$ is the probability to choose the intersection(j) from the intersection(i), $\tau_{i,j}$ is the pheromone amount on the road segment between intersection i and j, $\sum_{k=1}^n \tau_k$ is the sum of the pheromone in the whole path from intersection (i).

The *forward ant* K records every intersection it has passed. Every intersection has an identifier ID. Therefore, by each past intersection, the number of hops increases. Each *forward ant* keeps a list of the intersections it has visited.

4.2 The path establishment

Upon arrival at the destination D, the *forward ant* is converted into a *backward ant*. Using unicast transmission, the backward ant travels back to the source vehicle S following the reverse path. The backward ant sets up a path towards the destination D and then deposits and updates the pheromone in each go through intersection.

4.3 The pheromone deposit update

After the route exploration and establishment, the pheromone deposit is necessary for the other ants to follow the routing path easier. Through the return path from destination D to the source S by the backward ant, the pheromone value is updated or created. The process of pheromone deposit follows the equation (2) [14] below:

$$\tau_{i,j} \leftarrow \rho \times \tau_{i,j} + \sum_K \Delta \tau_{i,j}^h \quad \rho \in (0, 1) \quad (2)$$

where $\tau_{i,j}$ is the pheromone amount on the road segment (i, j), ρ is an evaporation coefficient, $k > 0$ is the number of road segments in the chosen path, $\Delta \tau_{i,j}^h$ are the increased pheromones on the road segment (i,j) of route h found by the backward ant. The pheromone increment-updating rule uses the ant-weight strategy presented by [15].

The iteration is repeated until all *backward ants* arrive to the source S. The route possessing the highest pheromone value is considered as the optimal path between source S and destination D.

4.4 The pheromone evaporation

A process of pheromone evaporation is applied at the trails/roads to avoid a rapid convergence to a local optimum. To imitate the real ant's pheromone, the mechanism of evaporation consists in decreasing the level of the pheromone value on all road segment links. As known, the choice of a path follows a probabilistic equation thus wrong decision can happen. Therefore, to make ants forget the low-quality routes, the pheromone should be evaporated according to the equation (3) [13] below:

$$\tau_{i,j} = (1 - \rho)\tau_{i,j} \quad (3)$$

where $\tau_{i,j}$ is the pheromone amount on the road segment between intersection i and j and ρ is an evaporation coefficient.

4.5 Updating the traffic information

If the path establishment is successful, a number of good paths between source and destination are made available. The intersections are updated with the information of the best path between the source S and the destination D. Otherwise, if no *backward ant* returns to the source S after a certain amount of time (1s), data are temporarily buffered and the whole process is restarted.

The main steps of the proposed algorithm are given in the flowchart illustrated in Figure 2.

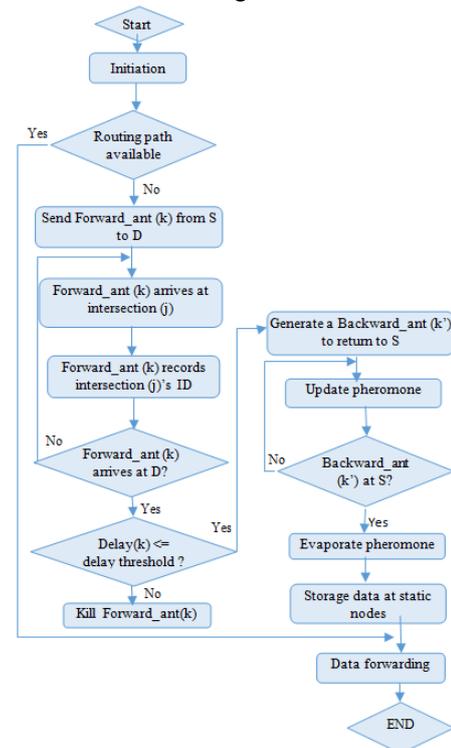


Figure 2. Flowchart of the proposed algorithm

5. Method

Considering the VANET infrastructure and features, this paper assumes that each vehicle is equipped with GPS facility, digital map and navigation system [16, 17]. With these equipments, the vehicles will have the ability to know their own speed, their geographical position and the position of intersections. With the help of the location service [18], the source vehicle is supposed to obtain the geographic location of its respective destination. To make the storage and the update of traffic information possible, a static node in each intersection is implemented. The VANETs have the same radio power that makes the data loss null. Moreover, it is supposed that the urban street map is abstracted as a square area with N vehicles scattered and distributed randomly. Obviously, the route between the source S and the destination D can be defined as a succession of intersections; supposing that M intersections in the area are connected by a set of road segments. Note that the intersection (1) is the first intersection connected to the source S, and the intersection (M) is the last one connected to the destination D. The reference vehicle is randomly positioned in the network. The proposed algorithm aims to find the best and shortest path between source and destination considering the best commitment between the delay and the minimum number of hops. To do so, it is assumed that for each road segment between two intersections, a delay threshold exists. For each hop, the delay made by the forward ant and the delay threshold is compared so that the shortest path in terms of time can be chosen.

The figure below illustrates and describes the proposed algorithm. The bases for implementation are as follows:

- First, after the random distribution of vehicles, neighboring intersections are to be found.
- If the routing path is available, data packet forwarding is implemented. Otherwise, forward ants are created.
- Forward ants start being sent. The first ant chooses the route haphazardly. The next ants will choose the route according to the probability given in equation 1.
- *For Every forward ant sent. Pheromone evaporation is applied according to the equation 3.*
- The ID of each intersection is recorded on each hop before choosing the next destination corresponding to equation 1.
- *When forward ant reaches destination D*, a comparison is done between the delays made by the ants and the delay threshold, in order to choose the shortest route in terms of time.
- If the ant's delay is bigger than the threshold, the forward ant is killed. Otherwise, a backward ant is generated.
- When returning to the origin, the pheromone table is updated according to equation 2, where the pheromone amount recorded on trails is updated.

- Notice that the obstacles and the radio power limit the search of neighbors for a given vehicle, therefore it would be wise to divide the simulation into three parts: static routing, static routing with obstacles and dynamic routing.

```

set running parameters
spread vehicles randomly

for i= 0 -> N (vehicles number)
    find neighboring intersection of vehicle(i)

    if routing path available at neighboring intersection
    then vehicle(i) implements data packets forwarding

    else create forward_ant
end for

for k= 0 -> N (vehicles number)
for j= 0 -> M (Intersections number)

    if forward_ant(k) arrive at intersection(j) then
        forward_ant(k) records the ID of intersection(j)
        choose next destination intersection (j+1)
        send forward_ant(k)

    else if forward_ant(k) arrive at vehicle(N) then
        ( if delay <= delay_threshold then
            forward_ant(k) <- backward_ant(k')
            backward_ant(k') return to origin S
            (if backward_ant(k') at vehicle(1) then
                evaporate pheromone
            )
        )
        else
            destroy forward_ant(k)
        )
    else if forward_ant(k') in return then
        update pheromone
    end if
end for
end for
    
```

Figure 3. The proposed algorithm

6. Conclusion

The choice of VANET routing research field is explained by the advantages and features it offers, such as the homogeneous network that results in the same physical capacity and the same radio power. Still, many challenges characterize the VANET environment including high dynamic topology, frequent disconnect network and others. This paper discusses the problem of routing protocols in VANETs; the proposed algorithm aims to find the shortest and the most optimal path considering the best commitment between the number of hops and the delay, thanks to the swarm intelligence techniques use a behavior similar to the living organisms in nature. This analogy with nature enables the use of the Ant Colony Optimization. The algorithm starts with a search of an existing routing path in static nodes, when a negative feedback is signaled. The proposed algorithm uses the ACO-algorithm to start a reactive search from source to destination. After the path setup phase, the algorithm probes the path by the level of the pheromone amount in the trails. The higher the pheromone amount is, the best routing path it is. Finally, an evaporation pheromone operation is implemented to avoid the convergence of a local optimum. The advantage exists in terms of average end-to-end delay, shortest path computed by the number of hops between source and destination, and the best

routing path information centralized in all static nodes at all intersections in the area. Nevertheless, the algorithm needs more performance in terms of routing overhead. As for future works, a simulation in three parts will be made, starting with static routing, static routing with obstacles and dynamic routing. In addition, congestion during rush hours in urban areas will be taken into consideration.

7. Future work and perspectives

To investigate the performance evaluation of our routing protocol, a simulation in three parts will be made as future work, starting with static routing, static routing with obstacles and dynamic routing. In the simulation experiments, we will use the Vehicular Ad Hoc Networks Mobility Simulator (VanetMobiSim [19]) with the network simulator NS-2 to generate vehicles mobility. In addition, congestion during rush hours in urban areas will be taken into consideration.

8. Acknowledgment

This paper was fully supported by the team of Information Research and Indexing Documents Texts and Multimedia at National School of Computer Science and Systems Analysis of Mohammed V University, Rabat, Morocco.

References

1. Melauouene, N., and Romadi, R. 2017. VANET's Applications and its systems based on RFID: state of the art. In *proceeding of CoDIT 4th Interational conference on control, decision and information technologies* (Barcelona, Spain, April 5-7, 2017).
2. Dorigo, M., Maniezzo, V., and Colomi A. 1996. Ant System: Optimization by a colony of cooperating Agents. *IEEE transactions on sysems, man, and cybernetics*. Vol. 26, NO. 1, (Feb. 1996)
3. Dorigo, M., and stützle, T. 2004. Ant colony optimization. *MIT press, (Cambridge, USA)*.
4. Mantilla-Gaviria, I. A., Diaz-Morcillo, A., and Tejedor, Jv. B. 2013. An Ant Colony Optimization Algorithm for Microwave Corrugated Filters Design. *Hindawi Publishing Corporation Journal of Computational Engineering*. Volume2013.
5. Kaur, S. Er. 2013. Shortest Path Finding Algorithm Using Ant Colony Optimization. *International Journal of Engineering Research & Technology*. Vol. 2 Issue 6 (June 2013), 2278-0181.
6. Kumar, R., and Dave, M. 2011. A comparative study of various routing protocols in VANET. *IJCSI international journal of computer science issues (July 2011)*. Vol. 8, Issue 4. 1694-0814.
7. Lee, K.C., Lee, U., and Gerla, M. 2010. Survey of routing protocols in vehicular ad Hoc Networks. *Chapter 8 in Advances in vehicular Ad-Hoc Networks: developments and challenges*. University of Wollongong, UK.
8. Silva, R., Lopes, H. S., and Junior, W. G. 2013. A heuristic algorithm Based on Ant Colony Optimization for Multi-objective Routing in Vehicle Ad-Hoc Networks. In *proceedings of the BRICS Congress on Computational Intelligence & 11th Brazilian Congress on Computational Intelligent* (Recife, Brazil, September 08-11, 2013).
9. Caro, G.D., Ducatelle, F., and Gambardella, L.M. 2005. AntHocNet: an adaptive nature-inspired algorithm for routing in mobile ad hoc networks. *Euro. Trans. Telecommms. (2005)*. 16. 443-455.
10. Toklu, N.E., Montemanni, R., and Gambardella, L.M. 2013. A Robust multiple Ant Colony System for the capacitated vehicle routing problem. *IEEE international conference on systems, man, and cybernetics*. DOI= 10.1109/SMC.2013.322.
11. Li, G., and Boukhatem, L. 2013. Adaptive Vehicular Routing Protocol Based on Ant Colony Optimization. In *Proceeding VANET'13 (Taipei, Taiwan, June 25, 2013)*.
12. Li, G. 2015. *Adaptive and Opportunistic QoS-based Routing Protocol in VANETs*. Doctoral Thesis. University of Paris SUD.
13. Blum, C. 2005. Ant Colony optimization: Introduction and recent trends. *Physics of life reviews* 2. (2005),353-373.
14. Bin, Y., Zhong-Zhen, Y., and Baozhen, Y. 2009. An improved ant colony optimization for vehicle routing problem. *European journal of operational Research*. 196, (2009), 171-176
15. Yang, Z.Z., Yu, B., and Cheng, C.T. 2007. A parallel ant colony algorithm for bus network optimization. *Computer-aided Civil and infrastructure engineering* 22. 44-55.
16. Song, X., Li, X., Tang, W., and Zhang, W. 2016. A fusion strategy for reliable vehicle positioning utilizing RFID and in-vehicle sensors. *Information fusion*. 31, (2016). 76-86.
17. Duchon, F., Hubinsky, P., Hanzel, J., Babinec, A., and Tlôlgyessy, M. 2012. Intelligent vehicles as the robotic applications. *ProcediaEngineering*. 48, (2012). 105-114.
18. Karagiannis, G., Altintas, O., Ekici, E., Heijenk, G., Jarupan, B., Lin, K., and Weil, T. 2011. Vehicular networking: A survey and tutorial on requirements, architectures, challenges, standards and solutions. *IEEE Communications Surveys & Tutorials*. 13, 4 (Jul. 2011), 584-616.
19. Harri, J., Filali, F., Bonnet, C., and Fiore, M. 2006. Vanetmobisim: generating realistic mobility patterns for vanets. In *proceeding of (VANET'06) IEEE international Workshop on Vehicular Ad Hoc Networks* (Los Angeles, USA, Sep.2006).