ISSN No:-2456-2165

A Survey of Nature Stimulating Routing Algorithms for VANET

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Abstract:- In order to improve road safety, appropriate decisions need to be taken for the transfer of messages from source node to destination node in Vanet. From the early days most of the inventions are made by man is only because of the inspiration of animal's behavior which surrounds him. From early age to modern age this problem solving technique always finds an optimal solution for any complex problems. Nature inspired algorithms are higher-level procedure that imitate the nature for solving optimization problems and produces an excellent result. Till now many routing protocols for Vanet have been proposed, but these protocols suffer from several limitations including Packet Delivery Ratio, Robustness, Routing Overhead etc. To overcome these limitations, various bio-inspired approaches have been proposed to transfer messages among vehicular nodes in an optimized manner. Still being a blooming area in research and the results produced are amazing, which broadens the usage of bio-inspired algorithms by surveying into new areas of application. This paper gives about a survey of the proposed basic bio-inspired routing algorithms for the Vanet environment. In specific, their strengths and weakness of these algorithms are specified in a detail manner.

Keywords:- *Vehicular Adhoc Networks, Intelligent Transportation System, Bio-inspired Algorithms, Routing, Optimization.*

I. INTRODUCTION

A Vehicular Adhoc Network (VANET) is one of the branch of Mobile Adhoc Network (MANET) from Computer Network. Vanet consists of a set of mobile nodes (vehicle) and fixed nodes known as Road-side units (RSU). There are two types of communication in Vanet. First, a communication between vehicles named inter-Vehicle Communication (IVC). Second, a communication between vehicles and RSU known as Vehicle-to-Roadside Communication (VRC). Vanet vehicles navigate into different regions such as highways, urban and rural areas. Moreover, each vehicle is designed with an on-board unit (OBU) and Global Positioning System (GPS) for short-range wireless communication either through IVC and/or VRC and location-based services.

An intelligent Transport System (ITS) safety application gives a significant impact on safety of human lives in Vanet. There are two types of ITS safety applications based on their Transmission modes. The first one is transmitting safety messages to other vehicles over *single hop* using fixed access point. Secondly, transmitting safety messages to other vehicles over *multiple hops* using a unicast mode. The informational carried by safety messages are location, speed, acceleration, brake state and even state of other vehicles etc.

In addition, safety messages enable drivers to take appropriate decisions on whether to proceed in the same path or to take diversion. In addition to safety messages there are also various types of comfort applications for Vanet which improves passengers travelling experience and provide information services such as locations of Fuel station, hotels, hospitals, Restaurants, Weather Forecast, etc.

It is necessary to develop an efficient routing algorithm which route packets from the sender to the receiver via a set of intermediate nodes with a high level of Quality of Service (QoS). This implies sending data between nodes with a minimum end-to-end delay and routing overhead, successful delivery of the maximum number of transmitted messages by optimally using the network bandwidth. There are two main transmission nodes in Vanet routing, the first one is called *Unicast*, which sends data packets to one destination. Secondly, *Multicast* is transmitting data packets to multiple destinations.

Vanet routing protocols are divided into two types namely *Topology-based* and *Geography-based* routing protocols. Topology-based routing protocol determines a transmission path between source and destination based on topological links. Some common characteristics among these protocols include the shortest path to the destination, definite accuracy to the destination, no repetition and successful delivery of messages. Some of the drawbacks include difficult in determining the routes, high end-to-end delays and routing overheads. Whereas geography-based protocols is routing of data packets between source and destination without any network knowledge. Some common characteristics among these protocols include robustness and successful delivery of maximum number of messages during congestion. Some of the drawbacks include end-to-end delays and lack of information which leads to inaccurate destination.

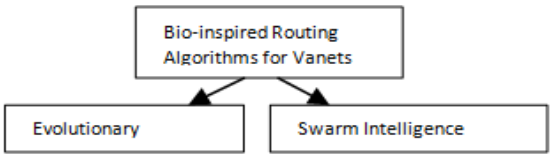
ISSN No:-2456-2165

Many routing protocols follow classical methods where theoretical ideas are influenced to obtain optimal routing solutions. But, such solutions are not suitable for complex vehicular networks due to their high complexity and low performance. Recently, a new area, called bio-inspired computing, which influence and inspire the biology of natural species. Now-a-days bio-inspired computing has created interest in many researchers because of its high throughput and ability in solving both theoretical and experimental problems in various applications. Bio-inspired computing has become a new era and cover wide range of applications in various computing and non computing fields. Classical problem solving methodologies involve two branches namely *traditional methods* and *heuristics methods*. Where heuristic approach is suitable in solving very large complex optimization problems compared to traditional methods. BIAs belongs to heuristics that imitate the nature of constrained optimization. In particular, biologically inspired methods have been used to address the routing problem in an efficient manner for transmission of safety messages in Vanet. The design of a bio-inspired algorithm involves

- Selecting an appropriate representation for the specified problem.
- Obtaining the quality solution using a fitness value.
- Taking random decision.
- Defining operators to generate new solution sets.

The two most successful classes in BIA involve *Evolutional Algorithms* and *Swarm Intelligence Algorithms, as* shown in Figure1. The Evolutionary Algorithms (EA) consists of computational techniques involves Inheritance, Mutation, Selection and Crossover whose aim to find an optimal route between the source and the destination. These algorithms are classical algorithms inspired by nature which is responsible for the design of all living beings on earth and to interact with each other. EA is designed in such a manner to find solutions for hard problems. In general, these algorithms are randomness and cost efficient optimization algorithm.

Figure 1. Classification of BIA for Vanet



The most successful EAs suitable for network routing is **Genetic Algorithm**. This algorithm is a population-based search algorithm which satisfies best-to-survive criteria.

Steps involved in Genetic Algorithm:

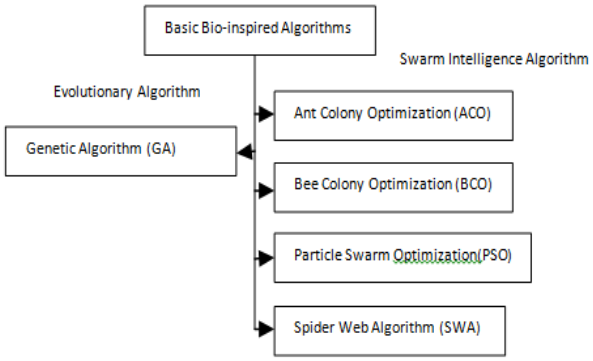
- Generating an initial population for feasible solutions
- Repeat iterations to obtain a best solution.
- In each iteration, fitness-based selection is made.
- Better solutions are selected for next generation solution.

Whereas Swarm Intelligence Algorithm (SIA) is an emerging prototype in bio-inspired computing. Actually, it is an extension of Evolutionary computations based on social behavior. The word "swarm" comes from the irregular movements of the particles in the problem space. These tracking algorithms are being inspired by the mannerism of ants, bees, spiders, birds etc. The final outcome is a self-organized behavior with simple rules used to fulfill their need such as foraging, reproduction, defense from predators etc. There are five Swarm Intelligence principles namely

1. *Proximit principle* for simple space and time computations.
2. *Quality principle* for quality environmental factors.
3. *Direct response principle* for definite solutions.
4. *Stability principle* for maintaining any environment changes.
5. *Adaptability principle* for sustainability in terms of computation price.

The most successful SIAs suitable for network routing is **Ant Colony Optimization (ACO), Bees Colony Optimization (BCO), Particle Swarm Optimization (PSO), Spider Web Algorithm (SWA).** The Algorithms that comes under basic bio-inspired category is shown in Figure 2.

Figure 2. Basic Bio-inspired Routing Algorithms



One of the most commonly used mathematical problems in all complex engineering disciplines is Optimization. Its main goal is to find best desirable solution out of many solutions. Hence, optimization problem in all areas are enormous. So methods are used for solving these kinds of problem have become an active research area. All optimization algorithms can be either ascertain or problematic in nature. At the same time, all traditional methods used these types of problem require huge computational efforts and are not suited as the problem size increases. This is the reason for utilizing bio-inspired problematic optimization algorithms. Multi-objective decision making are proposed for the iterative improvement of finding solutions either using Evolutionary Algorithms or Swarm Based Algorithms. This is mostly employed for solving any optimization problems.

Basic parameters of an Optimization problem:

- *Optimization problem definition:* selection of an optimal solution.
- *Search Space:* contains all feasible solutions.
- *Objective Function:* This is otherwise called as Fitness Function. It evaluates search space solutions to find maximum and minimum solution.

ISSN No:-2456-2165

- *Population and individual encoding:* Each independent represents a search space solution.
- *Initialization:* It is the starting values assigned from search space.
- *Stopping Criterion:* It is a measured value which controls the number of execution.

II. DETAIL NOTE ON BASIC BIO-INSPIRED CONCEPTS USED FOR VANET ROUTING

(a) Genetic Algorithms

Introduction

GA was introduced by Bremermann in 1958 and made popular by John Holland in 1975. This is one of the popular algorithm based on the inspiration of natural selection which follow the principles of Charles Darwin Theory of survival of the fittest. Since of its excellent outcome in Optimization, it acts as a function optimizer which yields an efficient solution [25]. GA is a global search algorithm used to solve more complicated problems by means of natural selection and natural reproduction of biology. It is one of the most successful class under Evolutionary Algorithms.

Process

GA begins with initial population and a single solution is called chromosome. That is solutions are extracted from the parent pollution and from that it produces new more successful offspring. Definitely the obtained new offspring are more efficient and improved one compared to the old parents. Then the produced new one is treated as a new parent in order to design new population depends on the fitness value. In each iteration, best chromosomes are selected into the coupling tool which undergoes genetic operations like Crossover, Selection and Mutation. The final output of genetic operation is the optimum solution of subsequent generation. These steps are repeated until any solution is found or terminating state is achieved. The main goal of GA is to find a highly optimized solution for complete problems. Similarly GA maintains varieties in huge search space. The whole problem is represented in bit vector.

Genetic Algorithm for Routing

GA obtain two solutions namely a *feasible solution* which is a path from starting node to target node and *best solution* is the smallest path from starting node to target node. Both solution produces string of nodes between source node and destination node. The feasible solution produces largest value which yield a highly optimized solution whereas unfeasible solution produces a zero fitness value.

The three principle *genetic operators* include

1. Selection
2. Crossover
3. Mutation

These operations are performed iteratively until a stopping criterion is reached.

1. *Selection Strategy:* Using various strategies the chromosomes are selected from the parents to the offspring for the next generation.
2. *Crossover Operation:* Two new chromosomes are produced using binary operation which is taken from either parent. There are various crossover strategies such as one-point crossover.
3. *Mutation Operation:* After crossover operation one chromosome is produced using unary operation. The main goal is to do small changes in the chromosome representation for finding a new solution similar to the original one in search space. There are various mutation strategies available such as one-point mutation, uniform mutation etc.

Advantages

- The search space may be huge or indefinite.
- Analyzing the problem in logical way is not needed.
- Deep knowledge is not needed to narrow down.
- It works on its own internal rules.
- Even traditional search method fails.

Drawbacks

- It produces local optima when the fitness function is not definite.
- Not applicable for dynamic data sets.
- Even simpler optimization algorithm performs well.
- It does not support constraint optimization problems.

(b) Ant Colony Optimization

Introduction

ACO comes under swarm based algorithm proposed by Dorigo and Di caro in 1999. ACO is one of the popular bio-inspired techniques highly suitable to solve complex optimization problem. This is inspired by the foraging behavior of ants known as stigmergy by Grasse in 1959. Stigmergy is a mechanism of indirect coordination through the environment between agents. The objective of the ant colonies is to find the shortest path between the nest and the food source.

Process

The characteristic of ant is to find the nearest route to the destination by tracing pheromone trails. The same pheromone track is used by the ants to bring the food back to the nest. On returning, it again deposits pheromone on the same way. The width of the pheromone depicts the quantity and quality of the supply source which act as a guidance to other ants. A probabilistic decision is made by the ants in following the path such as the stronger the pheromone trail, the higher its desirability. This enables the ants to find the nearest route between the nest and the source of nourishment. Not only ant foraging behavior even the other behavior such as young one's sorting, nest design, pattern formation etc helps to solve any complicated optimization problem eg. Travelling salesman problem. Finally ACO algorithm is called as the pheromone model which has two important mechanisms. First, the way the pheromone is sedimented in the paths and second, the way the pheromone is evaporated.

ACO for Routing

The ACO works with the principle of mobility of vehicles aiming to find routing paths in an optimal manner. The goal is obtained by maintaining a routing table for each node according to the pheromone. So according to the pheromone information, multiple route paths are recorded in the routing table. When the ant follow the same route then more pheromone is deposited which depicts the quality of each route between source and destination nodes.

Advantages

- Higher scalability and automatic load balancing.
- Support both wired and wireless network.
- Guarantees distributed intelligence with high robustness.
- Reduced communication cost.
- Well suited for dynamic network.
- Highly adaptive and decentralized.

Drawbacks

Stagnation problem is one of the major curse in this algorithm. It includes

- Formation of Congestion in the optimal path.
- Choice of selecting alternate path is reduced.
- On network failure the desired path becomes undesirable.

(c) Bee Colony Optimization

Introduction

BCO is an algorithm which is inspired by the foraging behavior of honeybee swarm, proposed by Karaboga and Basturk. These insects have organized societies. They have one or a few females responsible for the egg laying, while other members of the colony gather food and do other tasks. The nectar in the flowers act as a source of energy and pollen of small plants act as a source of protein. Mostly algorithms are classified into two, first are *foraging behavior* and second are *mating behavior*. Basically a single bee reveals a simple set of behavior policies such as migration, replication and death whereas a bee colony betrays complex behavior such as scalability and adaptability. Generally, in bee colony each member is assigned a name according to their jobs. A single *Queen for* reproduction, a few thousands of males called *Drones*, several thousands of sterile females called *Workers (Scouts)* and many young bee larvae called *Broods*.

Process

In foraging behavior, when the scouts bee finds its food, it return to the hive and deliver the information in terms of *distance, direction, quantity* and *quality* of nourishment. The other bees understood about the supply source by means of their visual, touch and smell. The scout bees do a dance performance in front of other bees which depicts the way of communication about the food resource. There are two types of dances namely, one is *round dance* and other is *waggle dance*. The round dance specifies only the direction where as waggle dance represents both the distance and direction of the supply source. The tempo of the movement indicates the distance between the food source and the hive. A fast beat represents very close to the supply source and a slow beat indicates far away from it. Even the leaning of the dance depict the direction between the nourishment and the sun respective to the hive. Even the other bees came to know about the quality of the supply source by the aroma when it is rubbed. Finally the amount of food resource is depicted by the wriggling of the bee. That is, more wriggling, the higher is the quantity. There are two types of phases, one is *Exploration phase*, where the selection process is made to become foragers and the number increases according to the quantity of the food. The second is, *Exploitation phase*, where the forager gets the food and then the decision is made according to the amount of the supply source.

In reproduction behavior, the Queen and the Drones reproduce many Broods using crossover and mutation operators called mating-flight. Then the new born Broods sorted with the previous population bees to form a new population. This represents a new solution to the problem. Next the selection of workers for food foraging imitates the selection of worst solution. Searching for best food in their area implies the best solution and comparison with the Scout bees depicts the neighbor solutions. The most selected bee in each area will form the next bee population. These steps are iterated when a stagnation state is reached or there is no improvement.

Bees Algorithm for Routing

Inspired by the sharing of information about the availability of supply source simulates the Vanet. The beehives match with a vehicle or a RSU and the bee's food resource match with a vehicle node or RSU. Whereas Intermediate vehicles or RSU corresponds to workers.

Advantages

- Best suited for Telecommunication.
- Explore multiple paths with quality guarantees.
- The communication cost is reduced.
- Distributed Intelligence is performed effectively.
- Even apply for Dynamic Network.
- Reduces Overhead.
- Maintain smaller routing table paths which determine the quality of nodes.

Drawbacks

- No additional information used.
- Need of new tests and parameters for new algorithm.
- Evaluation of more number of functions.
- Takes more time for serial operations.
- Don't know whether the solution found is optimal or even close to optimal.

(d) Particle Swarm Optimization

Introduction

PSO is a randomness and an uncertainty optimization technique proposed by Kennedy and Eberhart in 1995 [26]. Influenced by the mannerism of bird flocking, fish schooling etc. This is suitable for many complicate engineering problems for its simplicity, exploring techniques, problem solving and easy execution. It is a multi-objective algorithm which is suitable to develop random continuous function.

Inspired by the intelligence of swarm which is seen in groups named as school, colony, flock, team, caste etc. The PSO is a computational method that optimizes a problem iteratively by trying to improve a candidate solution with regard to a given measure of quality [28].

Process

A flock of birds flying in search of a place to land based upon the availability of food resource, minimum amount of risk, suitable environment to stay for a while or live long etc. when all the birds are satisfied with the selected place their action of landing is like the waves in the ocean. This action is performed only when the selected location is agreed by all the swarm members in the group otherwise the group is disturbed. The research on social behavior of swarm express that their ultimate goal is to find a right location to land by any one of the member in the group that is agreed by all. This represents that any individual's swarm knowledge is justified by all is known as social knowledge.

Swarm Algorithm for routing

The decision is made before landing in an appropriate place is considered as the survival condition [27]. A problem in finding the right location to land is represented as an optimization problem. So each member in the flock must recognize to enhance the survival conditions of its members. For that, each swarm must explore and evaluate various locations using surviving criteria simultaneously. Once the finest location is found will be shared by all the members in order to land in an appropriate place all at once.

Advantages

- It is easy to implement and needs few parameter adjustments.
- Availability of more memory capacity.
- Maintain all possible solutions for further improvement.
- Possibility to reach the optimal solution.
- Maintains steadiness in multidimensional complex space.

Drawbacks

- It requires complete knowledge about the given problem.
- It needs an ability to extract ideas into mathematical equations.
- It is very difficult to handle situations like out-of-bounds.

(e) Spider Algorithm

Introduction

The structure of spider web exactly match with the road structure of network topology in Vanet. Based on that many protocols are emerged to solve the problems regarding routing, security, different attacks etc in vehicular environments [29]. The behavior of the spider will quickly react to the prey that was trapped in the web. According to this many routing protocols are designed which emulate the spider behavior in finding the path to the prey. Not only that, even it is possible to determine multiple routing path composed of intersections. Once the feasible path is selected then by increasing the quality of connection and reducing the delay in transmission will yield an optimal path. Finally an optimal path is selected, many selective forwarding schemes are available to deliver data along the selected path.

Process

The spider web shows an overall uniformity in its structure. The structure is formed by means of *Spokes* and *Hypotenuses*. The spokes starts from the center of the web which form the framework of the structure whereas the hypotenuses around the center form many layer which look like concentric circles. Compared to other bio-inspired algorithm, the spider catches its prey in an intelligent manner by travelling through minimum distance to the spot. Each spider has large storage capacity which store information such as their present location, previous vibration, last action, idle state, different dimensions etc. Any shake on the web is considered as the source, it varies with different strength and it passes through different locations on the web.

Spider Web Algorithm for Routing

The structural arrangement of spider web model shows a resemblance of road network for Vanets through which message transfer take place. The road segment which forms a long route is named as the hypotenuses whereas the road segment joins the different junction are treated as spokes.

Advantages

- Improvement in trustability and indestructibility.
- Compared to classical networks, usage of hops number is less.
- The bond between nodes is better compared to other network structure.
- Shows steadiness in structure even when there is a network problem.
- Better in redundancy, dynamicity, security, lookup and queries.

Drawbacks

- Build and maintain a defined topology for the desired network.
- Using appropriate software to manage the network.
- Need to handle uncertainty and ambiguity at various points in the process.

III. LIST OF BASIC ROUTING ALGORITHMS IN VANET

Evolutionary Routing Algorithms

A family of successful EAs for Vanet routing is Genetic Algorithm (GA) by Holland [3], Genetic Programming (GP) by Koza [4], Differential Evolution by Storn [5], Evolutionary Strategy (ES) by Beyer [6], Paddy Field Algorithm by Upeka Premaratne [7], Intersection-based Geographical Routing Protocol (GRP) by Saleet [8], Optimized Link State Routing (OLSR) by Clausen [9], Adaptive Message Routing (AMR) by Saleet [10], Hybrid geographic and Delay Tolerant Networks (Hybrid DTN) by Cheng [11], XChange Mobile by Danoy [12].

Swarm Intelligence Routing Algorithms

Similarly, families of successful SI algorithms for Vanet routing are ants, bees, birds, spiders etc. Four sub-classes are categorized as Ant Colony Optimization (ACO), Bees Colony Optimization (BCO), Particle Swarm Optimization (PSO), and Spider Web Algorithm (SWA).

Under ACO, several Vanet routing protocols are available such as Mobility-aware Ant Colony Optimization (MAR-DYMO) by Correia [13], Trust dependent Ant Colony Routing (TACR) by Sahoo [14], Multicast with Ant Colony Optimization for Vanet (MAV-AODV) by Royer [15]. Under BCO, various Vanet routing protocols are Quality of Service Bee Swarm routing (QoSBee) by Bitam [17], Hybrid Bee Swarm Routing (HyBR) by Bitam [18], Bee Life Algorithm (BLA) by Bitam [19], Honeybee Swarm by Karaboga.

Similarly, Under PSO, several Vanet routing protocols are Parallel particle Swarm Optimization Algorithm (pPSO) by Toutouh [16], Swarm Intelligence [26] and On Swarm Intelligence inspired self-organized networking by Zhongshan [27]. Under SWA, several Vanet routing protocols are an Artificial spider-web-based Geographic routing (AGSR) by ChenChen [20] , Social Spider Optimization Algorithm by Luque-Chang [21], Research on Artificial spider Web Model by Jun Wang [22], A routing algorithm for region division by Lian-Suo Wei [23], TMED by Tie Qui [24].

IV. CONCLUSIONS

Coming to the conclusion of all GA-based routing protocols for Vanet, it is clear that these kinds of methods produce optimal result only for linear complexity. It lacks the connectivity, robustness and packet loss while transmitting packets. The rural regions are not applicable for these protocols. Similarly coming to the conclusion of all SIA based routing protocols for Vanet, it is clear that it is needed to be linear and realistic. Most of the protocols did not specify soundness of network connectivity which implies that it obtain strange results. In addition, bandwidth is also not considered as a one of the metric in considering Quality of Service. Like GAs, vehicular rural areas are not applicable to evaluate these protocols. We are sure that this survey paper will definitely be an eye opener for the researcher to make an excellent selection of any specified bio-inspired algorithm according to their problem to yield a remarkable solution. In addition, a new research work can be carried by them by analyzing the algorithm weakness.

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