

Research Article

Application of Hybrid Meta-Heuristic Algorithm for OLSR Protocol Optimization in VANET

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Accepted 02 May 2016, Available online 05 May 2016, Vol.6, No.3 (June 2016)

Abstract

The aim of VANET is to establish a vehicular communication system which is trustworthy and fast which caters to road safety. In VANET where network fragmentation is frequent with no central control, routing becomes a challenging task. Planning an optimal routing plan for tuning parameter configuration of routing protocol for setting up VANET is very crucial. Optimized Link State Routing Protocol (OLSR) is one of a famous proactive protocol used in VANETs. This paper evaluates OLSR routing protocol to better performance. OLSR protocol performs well in networks having frequent changing topology of nodes, as it can easily adapt in such environments. This is done by defining an optimization problem where hybridization of meta-heuristics is defined. The paper contributes the idea of combining Genetic Algorithm and Simulated Annealing algorithm (hybrid GA-SA) to enhance the performance of individual search method for optimization problem. In the experiments, tuned OLSR configurations results are more consistent due to better Quality of service (QoS) and communication efficiency than the standard making it fitting for utilization in VANET configurations.

Keywords: Genetic Algorithm, Simulated Annealing, Hybridization, Meta-heuristic, OLSR, VANET

1. Introduction

Vehicular Ad-Hoc Network (VANET) is the rising and important technologies which provide various services like Road traffic and Road Safety directly improving the Intelligent Transportation System (ITS) services. VANET provide communication among vehicles i.e. vehicle-to-vehicle communication as well as between roadside infrastructure i.e. vehicle-to-infrastructure communication.

It is independent self-organizing wireless communication network, where nodes in VANET involve themselves as servers and/or clients for exchanging & sharing information (Bijan Paul *et al* 2011). VANET, a special case of MANET, has distinctive properties. Vehicles move very faster than nodes in MANET gives shorter connection time between nodes and also generates specific mobility patterns

Many VANET routing protocols have been defined which caters to different application. These Protocols are broadly classified into topology based, Position based, Cluster based and broadcasting Protocols (Jamal Toutouh *et al* 2012). Topology based routing approach can be further categorized in to three groups: Proactive routing, Reactive routing and Hybrid routing.

In VANET network disconnection is frequent and route maintenance is harder compared to MANET. Mainly all the VANET application depends on the routing protocol used. Therefore an optimal routing strategy that makes better use of resources is crucial to deploy efficient VANETs that work in frequently changing network topology. So finding well-suited parameter for configuring the existing protocols is the way of improving their performance drastically (Jamal Toutouh *et al* 2012).

OLSR protocol is widely used to deploy VANET. It's a unicast proactive protocol which has simple operation but the continuous exchange (C. Gomez *et al* 2005) of control packets leads to network congestion thereby declining the performance of VANET, ultimately depending on the selection of the parameters. OLSR uses hop-by-hop routing where each node uses its local data to route packets. From C.Gomez *et al* work one can understand that OLSR has good capacity of improvement and can be optimally tuned by changing the configuration Parameters.

To resolve this concern, offline optimization problem has to be defined. The optimization problem is to find minimum cost protocol with respect to Quality of Service. This falls under the category of Combinatorial Optimization Problem where we have to find an optimal solution with minimum objective function i.e. communication cost. Number of possible combinations can be made hence this makes it very complex job.

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Therefore we make use of automatic intelligent tool, Meta-heuristic algorithms. In most of the optimization problem meta-heuristics are used as standalone method for solving the optimization problem.

But now the attention of researches is to use the concept of high level algorithm namely hybrid algorithms. In which two or more algorithm is combined to improve the quality of the solution and minimize the execution time. This paper introduces the idea of using hybridization of meta-heuristics by combining Genetic algorithm (GA) and Simulated Annealing (SA) i.e. Hybrid GA-SA for optimizing routing protocol thereby improving the Quality of Service (QoS) to apply to VANETs. The reason for choosing this hybrid method is explained in following section.

2. OLSR Protocol

The Optimized Link State Routing (OLSR) is proactive table driven protocol for mobile ad hoc networks. It provides efficient flooding of control messages throughout the network by using selected nodes called Multi-Point Relays (MPRs). Each node selects MPRs and is used to forward control messages. Also the node continuously maintains routes to all destinations in the network, thus making the protocol suited for random traffic pattern. The proactive nature makes OLSR suitable for networks where communicating nodes keep changing over time and it is suitable for dense network like for vehicular adhoc networks.

2.1 OLSR Operation

The core functioning of OLSR can be categorized into three processes:

1. Control Flooding Using MPRs: OLSR's proactive nature makes each node maintains the partial topology graph of the network. This information is extracted from Topology Control (TC) messages and used for calculating the shortest paths to destinations. A MPR node broadcasts a TC message periodically that is circulated across the network using the other MPR nodes
2. Neighbor/Link Sensing: Every node periodically exchanges HELLO message with each other. A hello message mainly consists of link information and neighborhood information, i.e., two-hop neighbors, MPRs and MPR selector. A MPR selector set of a node is a set that has selected it as its MPR. Tasks performed by hello message exchange are link sensing, neighbor detection and MPR selection signaling.
3. Optimal Path Calculation Using Shortest Path Algorithm: A routing table is maintained by every node, whenever a change in the topology is detected the table is refreshed and updated. To populate a routing table, shortest path algorithm is used on the partial topology graph obtained from TC messages.

2.2 OLSR packet format

All OLSR control traffic is based upon OLSR packets. An OLSR packet has an OLSR packet header consisting of the packet length and a packet sequence number maintained separately by each interface of the OLSR node. The packet body consists of one or more OLSR messages which are preceded by a message header for each incorporated message. The message header contains the message type, the validity time, the message size, the originator address, a time to live field, the hop count and a message sequence number. The originator address field contains the main address of the node the message. All OLSR traffic is sent in OLSR packets.

2.3 Types of messages

In order to maintain the topology information of the entire network which is highly mobile and has failures. The core functionality is performed mainly by using three different types of messages.

1. HELLO messages are exchanged between 1-hop distance neighbors nodes. It's used for link sensing, neighborhood detection, and MPR selection signaling. These messages are generated periodically, which has information about the neighbor nodes and about the links between their network interfaces.
2. Topology control (TC) messages are generated periodically by MPRs to indicate which other nodes have selected it as their MPR. This information is stored in the topology information base of each network node which is used for routing table calculations. Such messages are forwarded to the other nodes through the entire network. Since TC messages are broadcasted periodically a sequence number is used to differentiate between recent and old ones.
3. Multiple interface declaration (MID) messages are sent by the nodes to account information about the network interfaces employed to participate in the network. These information is wanted since the nodes may have multiple interfaces with different addresses participating in the communications.

3. Existing Solutions

Jamal Toutouh *et al* (Jamal Toutouh *et al* 2012) used meta-heuristics algorithms and applied to OLSR protocol for finding the optimized parameter for configuration. Four different techniques was used separately: Particle Swarm Optimization (PSO), Differential Evolution (DE), Genetic Algorithm (GA), and Simulated Annealing (SA).

R.K Chauhan and Arzoo Dahiya (R.K.Chauhan *et al* 2012) designed a scheme that avoids the delay of communication that occurs due to frequent disconnection in routing. For this, the Meta heuristic search i.e. ant colony optimization (ACO) is combined with AODV and route repair strategy is applied to ACO.

Pijush Kanti Bhattacharjee (Pijush Kanti Bhattacharjee et al 2012) , among the various Meta heuristics algorithm the Swarm Intelligence Technique has been implemented in AODV.

Tanuja Kumar (2009) studies the impact of mobility on the performance of two mobile routing protocols, AODV reactive routing protocol and OLSR proactive routing protocol. A basic framework is developed to analyze the performance of routing protocols.

C. Gómez, D. García et al (2005) used hybrid approach in various problems like a hybrid GA-TS (Genetic Algorithm - Tabu Search) algorithm is applied for optimizing networked manufacturing resources configuration.

Fatos Xhafa et al (2011) applied GA-TS for channel equalization and fiber tracking in wireless communication.

Bianchi, Leonora et al (2009) used Hybrid Genetic and Simulated Annealing to solve travelling salesman problem.

4. Problem Overview

4.1 Proposed Hybridization of Metaheuristics in VANETs

Optimization problem is deciding the best configuration as a set of parameters that best fits the exact behavior of VANETs. With countable parameters of the routing protocol but the number of combinations of value that take is more. So automatic intelligent tool like meta-heuristic is chosen in mainly the high level algorithm that is hybrid algorithms.

In hybrid algorithm not any particular meta-heuristic is used rather it combines the meta-heuristics algorithms consequently leading to hybridization of meta-heuristics.

Hybridization means trying to combine two or more algorithms to boost the performance of the single search method for optimization problems. This is to combine the best features of the combined algorithms into a new high level algorithm.

Hybrid models can be combined on two basis

1) type of methods - here we consider combining two meta-heuristics or meta-heuristics with explicit search method like any dynamic programming or AI techniques 2) level of hybridization-it refers to amount of coupling, the progression with which it is executed and control strategy. Level of coupling could be loosely coupled where the meta-heuristics preserve their flow i.e. high level of hybridization and strongly coupled where the hybrid meta-heuristics inter-change their inner procedures ie low level of hybridization. The series of execution could be sequential or parallel. The control strategy could be coercive where the one meta-heuristics has the main flow where as other is the subordinate to the main flow and cooperative where two meta-heuristics cooperatively explore different search space differently (Yan Zha et al 2013).

4.2 Hybrid Genetic Algorithm- Simulated Annealing (GA-SA)

Hybrid GA-SA algorithm is combining Genetic algorithm and Simulated Annealing. Here we combine the trajectory components in population-based methods. The power of SA Algorithm is the cooling schedule and acceptance criterion. The objective function drives the acceptance criterion and it also includes a changing amount of randomness. The decrease of the temperature factor drives the system from diversification to intensification. In GA selection, mutation and recombination procedure determines the diversification and intensification strategy.

The power of local area based methods is recognized in the way they explore a capable region in the search space. In this local search is the driving component, a capable area in the search space is searched in a more controlled way than in population-based methods. In this way there is less chance of missing a good solution as compared to population-based methods. Many hybrid approach has been used in many application and has shown successful performance. But unfortunately this hybrid approach in optimization problem in VANET is limited. We can see that population-based methods is superior in identifying possible areas in the search space, while trajectory methods are better in exploring possible areas in the search space. Therefore hybridization of metaheuristics in several ways deals to unite the advantage of population-based methods with the power of trajectory methods.

5. Methodology

We evaluated hybrid techniques that is hybrid Genetic Algorithm (GA) and Simulated Annealing (SA). These algorithms are chosen because they combine the best features of both algorithms. The accepted network simulator ns-2 is used in the fitness function evaluation of the solutions generated by the algorithms to simulate the search process.

5.1 Optimization framework

The optimization problem used to find automatically efficient OLSR parameter configurations is done by two different stages: an optimization procedure and a simulation stage. The optimization block is carried out by a hybrid metaheuristic method Hybrid GA-SA. These methods were used to find optimal solutions in continuous search space and simulation procedure for assigning a quantitative quality value to the OLSR performance of computed configurations in terms of communication cost. This method is carried out by means of the ns-2 network simulator which has been customized in order to interact automatically with the optimization procedure with the intend of accepting new routing parameters, opening the way for similar future research.

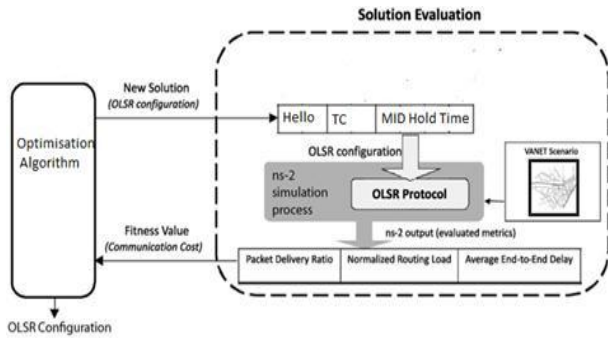


Fig.1 Optimization framework for automatic OLSR configuration

After the simulation gives global information about the PDR, the NRL, and the E2ED of the entire mobile vehicular network scenario, this information is used in turn to compute the communication cost (comm. cost) function as follows:

$$\text{Commcost} = w2 \cdot \text{NRL} + w3 \cdot \text{E2ED} - w1 \cdot \text{PDR}$$

Here , the Packet Delivery Ratio (PDR) is the fraction of the data packets originated by an application that are completely and correctly delivered.

End-to-End Delay (E2ED), that is the difference between the time a data packet is originated by an application and the time this packet is received at its destination.

The Normalized Routing Load (NRL) that is the ratio of administrative routing packet transmissions to data packets delivered, each hop is counted separately. The communication cost represents the fitness function of the optimization problem addressed. The objective here is to maximize PDR and NRL and minimize E2ED.

In this approach we used different biased weighs say, in the fitness function, being: $w1 = 0.5$, $w2 = 0.2$, and $w3 = 0.3$ and the communication cost can be calculated using the fitness function defined above. This way, Packet Delivery Ratio and NRL takes precedence over End to End Delay because we first look for the routing effectiveness and second for the communication efficiency.

5.2 Optimization Algorithm

Hybridization refers to the addition of problem-dependent information in a search algorithm. Hybridization models are classified as strong hybridization and weak hybridization.

Strong hybrids: algorithms in which knowledge has been incorporated as specific non-conventional problem representations and/or operators.

Weak hybrids: algorithms resulting from the grouping of lower-level hybrid algorithms

In hybrid GA-SA where the GA let to move to good regions of the search space, the SA allow to explore in an in-depth way of those regions of the search space. In this first GA executes until the algorithm completely finishes. Then the hybrid chooses some individuals from the final population and executes a SA algorithm over them. We use tournament selection for it.

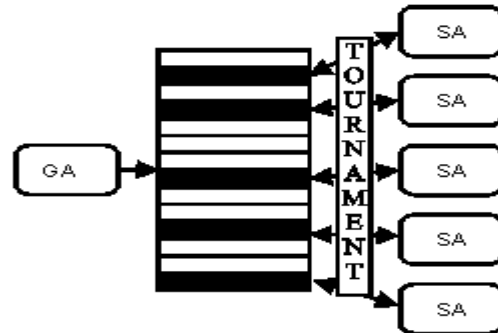


Fig.2 Hybrid GA-SA

5.3 Tuning of Parameters of OLSR

The standard configuration of OLSR offers a moderate QoS when is used in VANETs. Therefore, considering the impact of the parameters configuration in the full network performance, we solved the problem of the optimal OLSR parameter tuning in order to learn the best protocol configuration previously to the deployment of the VANET. The standard OLSR parameters are defined without clear values for their ranges. According to that , we use the OLSR parameters to define a solution vector of real variables, each one representing a given OLSR parameter. This way, the solution vector can be fine-tuned automatically by an optimization technique, with the aim of obtaining efficient OLSR parameters configurations for VANETs hopefully outperforming the standard one defined in the RFC 3626.

Table 1 Simulation Parameters

Simulation Parameters	Values
Simulation time	180s
Simulation Area	1,200 x 1,200 m2
Number of Vehicles	30
Vehicle Speed	10-50 km/hr
Propagation model	Two Ray Ground
Radio frequency	2.47 GHz
Channel bandwidth	5.5 Mbps
Routing protocol	OLSR
Transport protocol	UDP
CBR data flow	10 sessions

6. Simulation results

The simulation results are shown in the following section in the form of graphs.

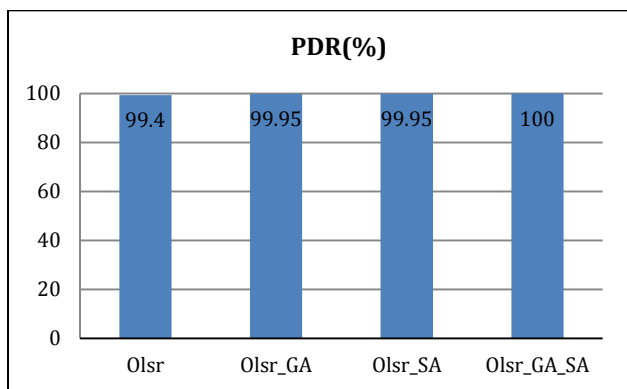


Fig.3 Comparison of Packet Delivery Ratio among OLSR, OLSR-GA, OLSR-SA and OLSR_GA-SA

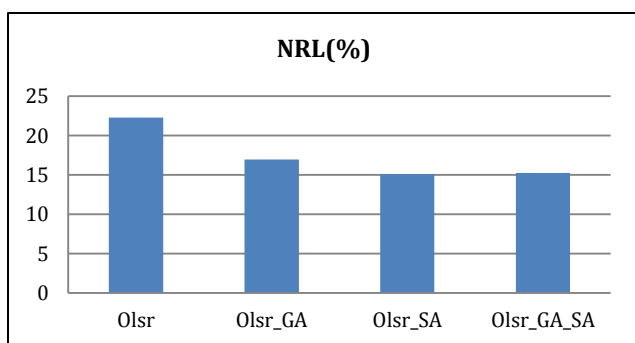


Fig.4 Comparison of Normalized Routing Load among OLSR, OLSR-GA, OLSR-SA and OLSR_GA-SA

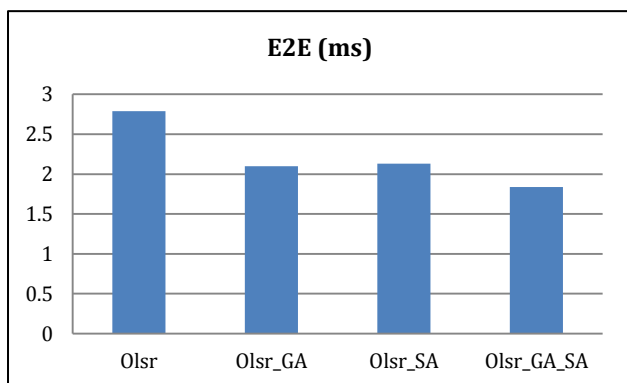


Fig.5 Comparison of End to End Delay among OLSR, OLSR-GA, OLSR-SA and OLSR_GA-SA

6.1. Packet Delivery Ratio comparison

As shown in Fig.3 graph shows comparison of OLSR with default configuration and optimized OLSR with Genetic algorithm and OLSR with simulated annealing and OLSR with hybrid GA-SA in terms of maximized Packet Delivery Ratio. Examining the PDR indicator, we can effectively check that the hybrid GA_SA obtained a 100% in contrast with individual algorithm. This is an important concern in highly dynamic VANETs, since a lower packet delivery ratio directly implies a higher packet loss, due to which OLSR protocol generates extra administrative packets with impacts in the network congestion.

6.2 Normalized routing load comparison

As shown in Fig.4 hybrid GA_SA optimized OLSR configurations showed better routing loads than others. Reducing the routing load is vital since this is a way to decrease the option of network failures related to congestion problem in VANETs

6.3 End to End Delay comparison

As shown in Fig.5 we can notice that hybrid GA_SA optimized OLSR performed better.

Conclusion

In this work, Optimization of OLSR protocol is Hybridization of genetic algorithm and simulated annealing and simulation of traffic is done using NS-2 Simulator. We got better results as OLSR with hybrid approach and outperformed the OLSR with GA, OLSR with SA and traditional OLSR. These results are compared and evaluated which indicate that performance gets improved in optimized OLSR (OLSR_GA_SA) protocol in terms of increased PDR and decreased NRL and end to end delay. In future, the same work can be extended by varying the hybrid Meta-heuristic eg GA with TS. The work can be extended by increasing the number of nodes and see the result of the packet Delivery Ratio and Normalized Routing Load on these protocols.

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