GPSR Routing Performances Enhancement for VANET networks with Taguchi Optimization Mechanism

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Abstract. Routing mechanism plays an important role in the performances of Vehicular Ad Hoc Networks (VANET). Hence, various routing mechanisms are proposed to enhance VANET performances, however few researches are dedicated to optimize these routing mechanisms. In this paper an optimization mechanism is proposed to improve the performances of Greedy Perimeter stateless Routing (GPSR) protocol. Design of Experiments is used along with Taguchi Optimization method to fine tune GPSR internal routing parameters against VANET network scenarios. The target of optimization in this work is set to network performances including network throughput, delay and packet delivery ration (PDR). These targets are mathematically combined to form a single optimization target. A simulation experiments are performed to evaluate VANET performances. Obtained results showed that the proposed optimization improves the VANET performances in terms of throughput, PDR and delay. Further real-time integration of Optimization and routing mechanism can improve network performances.

1. INTRODUCTION

The rapid changes in human life style derived by pandemics in year 2020 increased the need for real time internet access VANET. VANET aims to provide on road connectivity for various internet application. However, VANET suffers from degradation of network performances caused by the rapid mobility of its end-users (Vehicles). It’s crucial for VANET routing to adapt with mobility styles of vehicles.

VANET forms a multi-hop routing network. Where typical path information to last destination should be provided by the source node. Hence, the routing mechanism directly effects the network performances [1]-[3]. Proposed routing mechanisms classifications includes geographical, topological and bio-inspired. Geographical and topological are classified based-on the information used to calculate a path, while bio-inspired mechanism mimics a biological behavior of natural species.
Geographical routing utilizes the location information can be acquired with Position Information System (GPS) for calculating an optimum path [4]. Hence, a routing protocol maintains a set of protocol parameters to acquire and maintain this information such as time interval for periodic collection and dissemination of routing information. Similar set of parameters and settings are maintained by other routing categories. In literature these parameters are presented for a routing protocol, and hence this research work is dedicated to firstly investigate the effect of these parameters on VANET performance and then proposes and optimization mechanism to fine tune these parameters. Taguchi optimization mechanism is utilized to fine tune three routing parameters of GPRS. The selected GPSR routing parameters for optimization are: Bacon Interval, Maximum Jitter time, and Route Validity time. The impact of these parameters in VANET performance is investigated with set of simulation experiments in a separate section of this paper. Taguchi is a single objective optimization method, and hence optimization process results on optimized values for each targeted performance for a VANET scenario.

Next section of this papers describes the proposed Taguchi optimization method, followed by a brief description of GPSR routing protocol. The simulated networks scenarios are described in section followed by results section. The research and finding are concluded in conclusion section of this paper.

2. TAGUCHI OPTIMIZATION MECHANISM

Taguchi optimization method is firstly introduced by Genichi Taguchi in [5] for minimizing the production cost and increasing profit in manufacturing systems. In this paper Taguchi method is used for two main goals, the first one is to measure the effect of GPSR routing parameters. This objective is obtained by utilizing the delta analysis for GPSR routing parameters (refer to as control parameters). The second goal is to fine tune a set of control parameters to achieve optimum solution set for a given performance parameter. Taguchi method includes four steps namely: problem definition, experiment design, analysis, and validation.

2.1. Problem Definition

the optimization problem can be defined as: for a VANET scenario A define a set of GPSR control parameters (Bacon Interval, Maximum Jitter time, and Route Validity time) that: 1- minimize network delay, 2- Maximize network throughput. 3- Maximize PDR. Given that a set of noise introduced by user traffic. This step is depicted by a process diagram (P-Diagram) in “Fig. 1”. The P-Diagram consists of Noise, Control factors and output. Noise is refer to un recorded parameters that could effect the output. Control factors are the adhered three routing parameters, and output are the target of the optimization, here denote the delay, throughput, and PDR. As mentioned before Taguchi is a single optimization and hence, each output is optimized separately. Technically Taguchi uses a set of objective functions to either 1- minimize (1), as for delay. 2- maximize (2), as for throughput and PDR, or normalize a target output.

\[ LF_{smaller-the-better} = -10 \log \sum_{i=1}^{N} j^2 \]  

\[ LF_{larger-the-better} = -10 \log \sum_{i=1}^{N} j^2 \]  

(1)

(2)
2.2. Experiments Design

Taguchi is experimental based optimization method. This step starts by defining a set of \( n \) level for each control factor, followed by conduction a set of experiments based-on Orthogonal Array (OA) design of experiments. The OA is selected in respect to number of control factors and level. In this paper there are three factors and three levels for each factor. The factors levels are selected as the maximum, minimum allowed values of the inner-parameters and one intermediate value. These values are presented in Table I. The OA is denoted as \( L_k (N^m) \), \( k \) is the number of experiments in the design, \( N \) number of levels, and \( m \) is the number of factors. Here a set of 9 experiment will be conducted as in table II.

| Parameter                  | Level 1 | Level 2 | Level 3 |
|----------------------------|---------|---------|---------|
| Max Jitter (s)             | 0.1     | 0.5     | 1.0     |
| Active rout timeout (s)    | 20      | 30      | 40      |
| Hello Interval (s)         | 2       | 10      | 20      |

| No. | Beacon | MaxJitter | N.Validity Time |
|-----|--------|-----------|-----------------|
| 1   | 2      | 0.1       | 20              |
| 2   | 2      | 0.5       | 30              |
| 3   | 2      | 1.0       | 40              |
| 4   | 10     | 0.1       | 30              |
| 5   | 10     | 0.5       | 40              |
| 6   | 10     | 1.0       | 20              |
| 7   | 20     | 0.1       | 40              |
| 8   | 20     | 0.5       | 20              |
| 9   | 20     | 1.0       | 30              |

Experiment design steps is aimed to produce a measured value for each output, these measures values will be used in the next step.
2.3. Analysis
In this paper this step is used for two main goals: the first is to measure the effect of control parameters on the output. This goal is achieved by performing the delta analysis of loss function as depicted in. In “Fig. 2”, BeaconInterval with level 1 is presented in e1,e2 and e3 which implies the SNR1 is average for e1,e2 and e3. Repeating this calculation for level2 and level3 of the Beacon Interval yield SNRBeacon, L2 and SNRBeacon, L3. Then, the same process is applied to other control factors and the results is presented into two formats for analysis (“Fig. 2” and “Fig. 3” as graph format):

| Exp. No. | (Beacon, MaxJitter, N, ValidityTime) | T1    | T2    | T3    | T4    | T5    |
|---------|-------------------------------------|-------|-------|-------|-------|-------|
| 1       | (1,0,1,20)                          | 0.64994| 0.03242| 0.05244| 0.05268| 0.04925|
| 2       | (1,0,5,30)                          | 0.6386 | 0.07143| 0.06421| 0.06509| 0.0698 |
| 3       | (1,1,40)                            | 0.7008 | 0.06391| 0.05882| 0.06648| 0.0683 |
| 4       | (10,0,1,30)                         | 0.7011 | 0.06626| 0.06797| 0.06698| 0.08325|
| 5       | (10,0,5,40)                         | 0.6382 | 0.06856| 0.06998| 0.06644| 0.06384|
| 6       | (10,1,20)                           | 0.6999 | 0.06969| 0.06624| 0.06793| 0.06085|
| 7       | (20,0,1,40)                         | 0.6976 | 0.06556| 0.06466| 0.06803| 0.06821|
| 8       | (20,0,5,20)                         | 0.6954 | 0.07084| 0.06361| 0.06952| 0.07004|
| 9       | (20,1,30)                           | 0.6994 | 0.05242| 0.05344| 0.05268| 0.04925|

Figure 2. Delta analysis of AO Experiment Design.

Figure 3. Graph representation for GPSR control parameters.
2.4. Validation
Once the optimum solutions are obtained, a verification process is carried out through simulation experiments. The goal of the verification experiments is to compare between outputs values for different inner parameters configuration and the optimum configuration recommended by the TOM method.

3. GPSR ROUTING PROTOCOL
GPSR proposed for an aggressive geography to achieve scalability [9]. Initially designed for MANET, and later served as the basis of urban VANET. The GPSR is a stateless protocol allows nodes to figure out who its immediate neighbors are (using beacons) that are also near to the destination the information is supposed to send. This means that it does not try to preserve routes between sender and receiver, permitting to each node independently forward packets to the best neighbor. This minimizes the overhead of route discovery, maintenance, and does not waste resources in a useless to try maintain stable routes in a dynamic network for a prolonged period of time. The statelessness of GPSR makes it highly scalable, and the protocol is convenient to networks with highly dynamic changing topologies like VANET. GPSR uses Distance Vectors (DV), Link State (LS) and Path Vector routing algorithms. With DV, each node finds its receiver from its neighbors based on a periodic beacon. LS directly floods advertisement of changes in node status to every node in the network topology.

GPSR uses greedy forwarding algorithm to calculate a path, the strategy depends on sent a packet from the sender to the receiver using the most efficient path. Each node knows its direct neighborhood, it chooses a neighbor that is closer to the receiver than itself and forwards the packet. If there are multiple neighbors that accomplish this norm, the neighbor that is closest to the receiver is selected. “Fig. 4” illustrates the concept of geographically greedy forwarding [10].

![Figure 4. Greedy forwarding algorithm.](image)

If the greedy forwarding fails in scenarios, where the receiver node is closer to the sender node than any of the sources other neighbors, but stay outside the transmission range of the sender node perimeter. Forwarding will be used which routes around the perimeter of the region. This is illustrated in “Fig. 5” while nodes x and y both have a path to D, the greedy algorithm considers them sub-optimal next-hop routers since they are farther away from D then S itself.
If a node needs to forward a packet, but has no convenient neighbors, and there exists an unoccupied topological between one node and the purpose receiver. In such cases, GPSR switches to perimeter mode. Perimeter mode used the relative neighborhood graph (RNG) is an undirected graph defined on a set of nodes in the network topology by connecting two nodes by an edge whenever there does not exist a third node that is closer to two nodes than they are to each other. RNG remove link crossovers, and the packet is forwarded using the right-hand rule until the unoccupied topological is traversed and the packet can be returned to greedy mode [13].

The right-hand rule is used to overpass a graph without routing loops by thoroughly visiting every node in a specific fashion. The next node choose depends on selecting a node located at the smallest angle counterclockwise from the angle of entry. “Fig. 6” illustrated the right-hand rule mechanism in traversing through nodes in a polygonal region to find the next forwarder node [14].

GPSR have many problems that limit its work effectiveness in VANETs. Firstly, GPSR designed with MANET provides works best with the slow movement without obstruction. Fast movement nodes when using perimeter forwarding have to prompt routing loops, the protocol cannot effectiveness with VANET topological scenarios like highways with two-way direction traffic and crowded cities with a large structure [15]. Secondly, perimeter forwarding can increase in hop count and end-to-end delay, since the packets are forwarded to the nodes nearest neighbor instead of the most optimal neighbor. Finally, GPSR have not the capability to define the location of the goal receiver node, it using the greedy forwarding and perimeter forwarding with the assumption are known the receiver node. GPSR used the Grid Location Service (GLS) permits the construction of ad hoc mobile networks that scale to a larger number of nodes and define the receiver node location.
4. RESULT AND DISCUSSION
The goal of these sets of experiments is to analysis and investigate the effect of VANET’s multi-scenario phenomenon with its rapid topology changes and its correlation with routing protocols’ parameters on the performances of VANETs. Consequently, the effects of three routing parameters (Hello Interval, Route Time Out, and Maximum Jitter) of GPSR are evaluated against VANET performances. The effects of these parameters are compared and studied in city and highway VANET scenarios in terms of delay, PDR and throughput. The City and highway simulation parameters used in these experiments are described table III.

| Table-III: VANET simulation scenarios parameters. | City | Highway |
|-------------------------------------------------|------|--------|
| Dimension                                       | 1000m x 800m | 2000m x 20m |
| Vehicles speed                                  | 30 – 70 km/h | 80 – 110 Km/h |
| Number of Vehicles                              | 30 – 60 | 20 – 40 |
| Number of RSU                                   | 7 | 8 |
| Communication range                             | 300m | 300m |
| MAC protocol                                    | IEEE 802.11p | IEEE 802.11p |
| Data rate                                       | 18 Mbps | 18 Mbps |
| Traffic generation model                        | Burst application | Burst application |
| Packet size                                     | 1024 byte | 1024 byte |
| Mobility model                                  | Linear, rectangular, trace | Linear |

“Fig. 7-9” represents the obtained results for the effect of Max-Jitter, Beacon Interval, and Neighbor validity time in Network delay for two VANET scenarios. The obtained results show that, the value of each control parameter has a direct impact on the VANET performances, and hence fine tuning these parameters can result in improving the network performances.

Figure 7. GPSR MaxJitter effect on delay performances of two VANET scenarios.
Figure 8. GPSR Beacon Interval effect on delay performances of two VANET scenarios.

Figure 9. GPSR Neighbor Validity Time effect on delay performances of two VANET scenarios.

5. CONCLUSION
This paper presents the effect of routing parameters on VANET performance for two network scenarios. The Taguchi optimization mechanism is described as an optimization solution, and a set of experiment are conducted to present the effect of GPSR routing parameters in VANET performances. The obtained results show that VANET performances can be improved by fine tuning the GPSR routing parameters. Lastly the need for online optimization that can adapt to rapid topology changes in VANET is a required to improve VANET performances by reducing the effect of rapid topological changes in VANE.

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