Design and Development of GreedLea Routing Protocol for Internet of Vehicle (IoV)

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Abstract. In Internet of Vehicle (IoV), each vehicle uses a routing protocol to find a path for sending its messages to the last destination. Nowadays, the studies of IoV routing protocols and their impact on the performances of network with different network scenarios has significantly developed a precise understanding of the requirements and goals for designing an IoV routing protocol. In IoV, topology of network diverse promptly which leads to the fragmentation of network, frequent route breakage, and packet loss. This paper discusses on the development of an integrated routing protocol for IoV scenario. Greedy Perimeter Stateless Routing (GPSR) and Reinforcement Learning (RL) is integrate to determine a route based on demand. Then, the mobility model has been designed to reduce road collision. Lastly, traffic management also been focused to deal with the loss, mobility and network delay to meet the application demands.

1. Background
IoV is a superset of Vehicle Ad-Hoc Network (VANET). IoV enhanced VANET’s applications, scale and structure. Its aims is to preserve and enhance travel comfort and to provide real time traffic information to vehicle drivers smoothly. Generally, IOV is use in both urban and rural traffic environment to allow network access to traffic management, vehicles and drivers. The motivation behind improving conventional transportation system is due to traffic congestion and accident which leads to low road efficiency. Growing number of vehicles in the traffic system may composed to the increasing number of traffic accidents. In the IoV, communication is generally known as Vehicle to Infrastructure (V2I), Vehicle to Everything (V2X) and Vehicle to Vehicle (V2V). Figure 1 shows the communication in IoV.
2. Internet of Vehicles (IoV) Concept

Nowadays, number of vehicles on the road has increased significantly. It can be concluded that one fourth of the vehicles will be connected to internet and by the year of 2020, the worldwide vehicular traffic is believed to reach 300 000 Exabyte. IoV concept typically refers to vehicles and infrastructure which are linked to all IP-based infrastructure, able to transfer information immediately and capable to solve some problems, in order to produce more safe, efficient and new vehicle system. The development of an IoV environment must meet some requirement such as:

- A scenario-driven method through a comprehensive analysis for several scenarios expected to form part of internet-connected vehicles.
- Autonomic management systems expanding the internet-connected vehicles operation:
  - Generating outputs based on a per-scenario to enhance the internet connected vehicles performance
  - Vehicle, driver and environment modelling for assuming personalized information to be used in context handling
  - A comprehensive efficient and system architecture for IoV, based on current standards and providing expansion when needed.

3. IoV Routing Protocols Classification

IoV’s routing protocols classification has been a focus topic for several works recently [1], [2], [11], [3]–[10]. IoV’s routing protocols can be classified into three categories; geographical, topological and bio-inspired divided in network routing protocols. The first aspect is with regard to geographical routing protocols which uses the advantages of positioning systems in vehicles to find a path by utilizing the location information of nodes. The second aspect relates to the criteria used to determine topological routing which calculate the path by distributing topology information between vehicles. Moreover, topological algorithms are divided into reactive, proactive and hybrid protocols. Further geographical protocols divided into greedy and stateless, street aware, connectivity aware and infrastructure assisted protocols. Furthermore, the classification are classified into revolutionary and Swarm intelligent protocols added into a new paradigm of routing protocol based on bio-inspired algorithm. Figure 2 depicts the taxonomy of this classification. In this research, GPSR routing protocol has been used and integrated with reinforcement learning method to propose a novel robust routing protocol for IoV environment. GPSR is a stateless protocol that allows nodes to figure out who is its immediate neighbors which is near to the information destination. This implies that it does not attempt to preserve routes between sender and receiver, permitting to each node independently forward packets to the best neighbor. The statelessness of GPSR makes it highly scalable, and the protocol is convenient to networks with highly dynamic changing topologies like VANET. GPSR expends Link State (LS), Path Vector and Distance Vectors (DV) routing algorithms.
Figure 2. Taxonomy of network Routing Protocols Classification.

4. Reinforcement Learning (RL)
RL algorithm is a process of learning that connect through the environment by generating action and determine error or reward. The most significant features of RL are trial and error search and delayed reward [12]. This process permits software agents and machines to automatically regulate the ideal behavior of network environment in a particular context in order to increase its performance [13]. Markov Decision Process (MDP) is the example of RL. This research explores the idea of utilizing the vehicles in an attempt to solve routing in an IoV environment. The idea of dynamic rewards within the environment for the vehicles are incorporated based on analysis of many of the latest advances in traffic routing strategies, reinforcement learning and multi-agent interaction. RL algorithm is the most effective way in the unknown environment because the priori knowledge of environment is not required with this method. Therefore, the vehicle has the ability to select the optimal location from the experienced location sequence in the process of Markov Decision. The vehicles adjusts its behavior through trial-and-error interactions in the dynamic environment without the model of its IoV environment.
5. Related Work
This section provides a general review of different elements related to routing protocols for network. The main goal is however to present the evolution and classification of network routing mechanisms including bio-inspired, geographical and topological routing protocols. A summary of the reviewed work is presented in table 1.

Table 1. Comparison of the reviewed network Routing Protocols.

| Protocol                                      | Class                                           | Routing Algorithm | Routing Metric       | Conclusion                |
|-----------------------------------------------|-------------------------------------------------|-------------------|----------------------|---------------------------|
| Greedy Perimeter Coordinator Routing (GPCR)   | Greedy and stateless routing protocols (GSR)    | beaconing         | Street & junction    | Map based                |
| Intersection-Based Geographical Routing (IGRP) [14] | Infrastructure assisted protocols (IAP)         | Infrastructure    | Delay, bandwidth and error rate | Channel condition         |
| Geographic Stateless VANET Routing (GeoSVR) [15] | Connectivity Aware Protocols (CAP)              | Dijkstra          | Link life time, hops |                          |
| Multicast with Ant Colony Optimization based on MAODV (MAV-AODV) [16] | Ant Colony Optimization (ACO)                   | Multicasting      |                       |                          |
| Best-Energy Aware OLSR (BEA-OLSR) [17]        | ACO                                             | Proactive         | Energy               | Reduces PDR 8%            |
| Intelligent Optimized Link State Routing (IOLSR) [18] | ACO                                             | Proactive         | Routing Parameter    |                          |
| Trust dependent Ant Colony Routing (TACR) [19] | ACO                                             | Cluster           | Pheromones           |                          |
| Parallel Particle Swarm Optimization - Ad Hoc On-demand Distance Vector (pPSO-AODV) [20] | ACO                                             | Reactive          | Routing Parameter    |                          |

Consequently, a summary of the reviewed work presented to address the advantages and disadvantages with respect to each category; thus highlighting the goals, merits, research gap and problems in each class of routing protocols. In recent years, the analysis of IoV routing protocols and their impact on the performances of network with different network scenarios has significantly developed a precise understanding of the requirements and goals for designing an IoV routing protocol. Further, in the literature many routing protocol mechanisms has been propose to deal with IoV’s requirements. Nonetheless, proposed routing mechanisms in the literature considered a single network scenario in IoV. However, vehicles or moving nodes in IoVs are tend to travel in long distances, which implies their engagement in multiple network scenarios and topologies. The adhered behavior of VANET’s nodes results in a need for a routing mechanism that addresses the requirement of more than one network scenarios and topologies. This problem is less considered in the literature. The IoV routing protocol must capably to manage a fragmented network and prompt change of topology. Nonetheless, existing well-known routing protocols unable to fully address these particular requirements.

6. Research Design and Procedure
RL algorithm is a process of learning that connect through the environment by generating action and determine error or reward. This process is integrated with Greedy perimeter Stateless Routing (GPSR)
The integration of RL algorithm and GPSR routing known as GreedLea routing. Each protocol is firstly design for two different IoV scenarios (City and Highway) in-terms of its routing parameters to improve a certain performance metric. Further, the selected protocols are modified to automatically change their routing parameters values according to the current network scenario. Three metrics (throughput, delay, packet delivery ratio) are selected as a target for improving the network performances in this research. The research process is depicted in figure 3. The process consists of three stages:

- Routing parameter selection
- GreedLea-routing design and implementation
- Results and Evaluation

GPSR routing is designed for self-configured, mobile and scalable networks. GPSR routing consisted of basic routing operations such Route discovery and route maintenance. Thus, to accomplish these operations a set of inner-parameters are used to guard these operations from being dragged to unexpected situations such as: count for infinity with the use of sequence number and maintaining a route freshness in the routing table.

The first phase will focus on identifying the potential protocols parameters to be fine-tuned in the integration process. The selection of routing parameters is based-on the protocols tunable. With the parameters selected, each protocol will go through a simulation performance analysis to identify the effect of each parameters in the network performances. This stage resulted in a list of three inner-parameter to be fine-tuned in the integration stage.

The second stage emphasis on the design of the GreedLea routing that is aimed at obtaining the best performance of a routing protocol when a network device moves from one network scenario to another. The flow of the proposed routing model is start with the data transmission using GreedLea routing. In the GreedLea routing, data are being transmitted using two method. The transferred data from RouteSel
process will be goes to RouteBea process before being process as a profile mapped to the desired IoV environment. Further, the TraMan process select the best profile for the current running.

The third stage focused on the implementation, evaluation and analyzation. The discrete event simulator OMNET++ 5.0 and the INET 4 framework is used for these purposes. The proposed GreedLea routing is evaluated and tested for IoV scenarios specifically the highway and city. Vehicles mobility and placement will be achieved by utilizing the mobility modules.

7. Proposed GreedLea Routing Model

This section discusses on the proposed new routing protocol named GreedLea Routing. GreedLea Routing is the integration of GPSR routing with RL method that proposed to manage a fragmented network and prompt change of topology. The research design and procedure is one of the most important parts of this research, it consists of three steps including routing algorithm, mobility model, and traffic management. An efficient IoVs routing protocol is designed using geographical information to handle highly dynamic topology, different communications environments (e.g., in city, highways etc), and time-constraints applications. In the next step, mobility model is developed by using detailed synthetic and actual mobility traces in large obstacle environment and high mobility. In the third step, a traffic management is studied to deal with the loss, mobility and network delay to meet the application demands. Figure 4 shows the flow diagram of the GreedLea Routing Method. Further, the RL method is integrated with the GPSR routing as profiles mapped to the desired IoV scenario.

![Figure 4. GreedLea routing flow diagram.](image)

7.1. RouteSel Process (A)

In this research, an IoVs routing protocol is developed to adapt network situation by integrating real time traffic information, path stability and geographical forwarding. An integrated routing protocol is designed to discover routes. GPSR routing is used for the development of GreedLea Routing Protocol. This protocol implements two modes of operations (greedy and perimeter) to forward data. Greedy mode starts by calculating the distance between the position of the last destination and the current node, and finds the shortest path from a neighbor’s table. Perimeter forwarding mode utilizes neighbor’s table to construct a planar graph for the network topology. Data in GPSR are preferred to be forwarded in
greedy mode. However, greedy mode might fail to find the shortest path to a destination. Hence, the perimeter is used when greedy mode is failed.

7.2. **RouteBea Process (B)**

The second type of message implemented by GreedLea Routing is the Beacon message. Beacon is used for the beaconing mechanism in GreedLea protocol. GreedLea routing requires each vehicle to periodically send a beacon contains nodes identification and location to its neighbors. This mechanism is used by GreedLea routing to build and update its neighbor’s table. Once a beacon is received, a receiving node firstly check if the sender is in its table or not. In case the sender is in the table, the node updates the table with time of receiving the beacon, and if not in the table, the receiving node adds the sender to its table. This step is followed by recalculation of the network planar graph. Moreover, beaconing mechanism removes a neighbor node from the table if no beacon or packet is received from that node for a certain duration of time called Neighbor Validity Time.

7.3. **MobMod Process (C)**

Mobility model is an important element in designing networking protocols for Vehicular Networks. A practical mobility model for urban areas is particularly important to predict the network capacity, efficiency and infrastructure requirements. In this research, Mobility Model Generated for Vehicular Network (MOVE) is used for mobility model. MOVE comprise of two modules, which is the vehicle movement editor and road map editor. MOVE is develop using RL method. A RL table is establish between each state of the environment and each potential location while the vehicle keep exploring in the IoV environment. The proposed models allows vehicles to accelerate at maximum safe speed to make sure there is no collision with the prior vehicles. Since city and highway scenarios are targeted, proposed mobility model will consider traffic light system at the road intersection, multi lane and bidirectional traffic. The large-scale network simulations is performed using detailed mobility traces together with an accurate urban map that includes street direction and lane description, stop signs, traffic lights and their timing, building shape and height.

7.4. **TraMan Process (D)**

GreedLea routing implements the afore-mentioned mechanisms to process the routing profile. The last part of the development is the traffic management (TraMan). In TraMan process, each vehicle in the network will selects the closest Roadside Units (RSUs) as its parent RSU, and then acquires its routing profile by sending a profile request message (Profile REQ) to its parent RSU. GreedLea routing selects parent RSU based-on the geographical distance, where the closest RSU to the running vehicle is selected as its parent RSU. Once an RSU receives a profile request from a vehicle, it replies with the newest routing profile in a response message (Profile REP).

8. **IoV Simulation Scenario**

IoV scenarios that is implemented in this project are designed based-on the roads and traffic in city and highway scenarios. The geographical placement of the highway crossing the city is suitable for the purposes of evaluating the proposed mechanisms in a combined scenario. Table 2 shows the key simulation parameters of IoV scenarios.

| Parameter                  | City                | Highway              |
|----------------------------|---------------------|----------------------|
| Simulation area            | 1000m x 1000m       | 50m x 2000m          |
| Number of Vehicles         | 30 ~ 60             | 20 ~ 40              |
| Number of RSU              | 5                   | 5                    |
| Vehicle’s Speed            | 40 ~ 60km/h         | 80 ~ 110km/h         |
| Simulation time            | NILL                | NILL                 |
| Data packet size           | 512 ~ 1024 bytes    | 512 ~ 1024 bytes     |
| Vehicle Mobility Module    | Road trajectory     | Linear               |
9. Issue of Reliability and Validity
Some data in simulation (e.g., obstacles) might not be in real time and will be delay-tolerant. There is no limitations of storage data. Data is sent to the node by the access points in the transmission range. It is impossible to deliver data to more than one destinations.

10. Network Performance Evaluation
The goal of evaluation is to measure the effectiveness of the proposed methods in the performances of IoV network. To accomplish this goal, three performance metrics will be used (throughput, delay and Packet Delivery Ratio (PDR)). Further, these metrics will be evaluated for four design metrics (mobility, traffic generation, packet size and simulation pause time).

Figure 5 shows the PDR observations of GreedLea, GPSR, DSDV and DYMO routing for twenty (20) nodes in multi network scenarios. GreedLea routing achieved almost 100% PDR in multi scenario, and GPSR routing obtained PDR is between 91% and 93%. DSDV routing maintains its PDR in an average of 87% in both single scenario and multi scenarios which obtained PDR in varies between 86% and 88%. The observed PDR for DYMO routing in multi scenario increases compared to single scenario. From the observation, it shown that the PDR for all routing are increase as the number of node increase. This is because each node interact with each other to deliver the packet from source to the desired destination.

![Figure 5. PDR vs Node for multi scenario](image)

11. Conclusion
With increasingly growing number of vehicles, road traffic has become major problem of urban area. The integration of IoV can solve various traffic problem effectively. It plays an important role in enhancing road utilization, reducing energy consumption, reducing pollution and improving road safety. IoV is an integrated network that is capable to deliver vehicle smart control, smart dynamic information service and smart traffic control. This paper focuses on designing and developing an integrated routing protocol to manage hugely dynamic topology, packet loss, sparse connectivity and intermittent connectivity. Second, the development of IoV mobility model for highway and city scenario to establish realistic communication between vehicles in highway and cities. Lastly, the development of a novel IoV traffic management solution to overcome the large number of nodes participating in a transportation network. From the simulation result, it shows that the proposed GreedLea routing provided better PDR percentage compared to other existing routing protocol.

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