Position-based Routing Protocols of Vehicular Ad Hoc Networks & Applicability in Typical Road Situation

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Abstract: The exchange of information between vehicles is a challenging issue for future Transportation applications. In vehicular Ad-Hoc network, the vehicles are interconnected with each other and they have not any additional infrastructure along the roadside. Vehicular Ad-hoc networks are eminent from other types of Ad-hoc networks. The Ad-hoc network attributed to their features such as infrastructure-less setup and self configure without any centralized manager. The Vehicular Ad-hoc networks have hybrid architecture and due to high mobility the network pose various research challenges. Due to high mobility in Vehicular Ad-hoc Networks (VANETs), the various protocols proposed and have been made. In this paper, we studied the position based routing protocols and compare their performance in urban and highway environment and analyze which protocol is best for these environments. Position based routing protocols are based on the vehicle position. The urban and highway environment is different from each other we surveyed the differences and characterizing and analyzing the protocols with each other's. We also discuss the differences between mobile Ad-hoc networks and vehicular Ad-hoc networks and routing strategies as well.
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Keywords: Vehicular Ad-Hoc network (VANET), Intelligent Transportation Systems (ITS), Mobile Ad-hoc Networks (MANET)

1. Introduction

The Intelligent Transportation Systems (ITS) emerge the communication technologies with transportation for vehicular safety, mitigate traffic congestion and for controlling the traffic etc. The Intelligent Transportation System (ITS) is using various technologies such as wifi, wimax, bluetooth, Ad-hoc communications, wired communications etc depends on applications. Wireless communication technologies are undergoing rapid advancements. In ITS one of the most promising technology is Vehicular Ad-Hoc network (VANET). In Ad-Hoc network the mobile and fixed nodes are communicates through single or multi-hop routing protocols without wires and without infrastructure. This type of communication between nodes is called Ad hoc network. In Ad hoc Networks the mobile nodes are communicate with each other using multi-hop wireless links and when this Ad-Hoc technology implement in transportation sector, so it is called VANET. The Vehicular Ad-Hoc networks are self-configuring and provide communications required to deploy Intelligent Transportation Systems (ITS). The VANET provides the facility for vehicles to instinctively and wirelessly network with other vehicles nearby. Vehicular Ad-Hoc network (VANET) is a special class of Mobile ad-Hoc networks (MANET) but with own unique characteristics. Most of the solutions have been proposed for MANET but these solutions are not suitable for VANET. In vehicular Ad-hoc networks the nodes are operational with on- board computers, sensors, element of roadside infrastructure and pedestrian personal devices smart phones etc. The various studies showed that VANET have different types of applications and environment that are not match with MANET (Füßler, Mauve, Hartenstein, Käsemann, & Vollmer, 2003). Thus, a considerable effort is being put to design solutions for VANET and number of projects developed by car companies such as Networks on Wheels (NoW) (Festag, et al., 2008) and CarTALK 2000 (Reichardt, Miglietta, Moretti, Morsink, & Schulz, 2002), and recent projects are CVIS (Cooperative Vehicle-Infrastructure Systems), SAFEPOT,COOPERS(Co-operative Systems for Intelligent Road Safety) and eCoMove etc. These projects have different purposes like design for dynamic cooperative networks, unified architecture for road safety and development of cooperative traffic, eco-friendly driving as well. The standardization bodies International Organization for Standards (ISO) and European Telecommunications Standards Institute (ETSI) TC ITS, TC204 WG16 (ITS Communications) are developed for VANET communication and enhance the performance of Intelligent Transportation System (ITS). Communication Intelligent Transportation System and its applications use variety of wireless communications and air interfaces protocols which defined by Access for Land Mobile (CALM). Another important contribution was Wireless Access in Vehicular Environments (WAVE) by IEEE (Institute of Electrical and Electronics Engineers) made. Wireless Access in Vehicular Environments (WAVE) is specially design for VANET. In our study, we elaborated the typical situation such as urban and highway situations and focused on position based routing protocols for these situations and compare with each other.

2. Differences between VANET & MANET

We discuss some of major differences of VANET with MANET in this section. The major differences between Vehicular Ad-hoc networks and Mobile Ad-hoc networks are relates with communications, environment, applications etc. The one of the main difference is highway and urban environment is node mobility. In MANET, the nodes can move freely and considered the end-system. The nodes are shared own communication resources with other nodes. The VANET scenario is totally changed with MANET, VANET have a physical street maps, road maps, highways, traffic lights etc, and these have restriction between movements of vehicles. Buildings and other obstacles are affected with communication process and due to this, the inadequate signal propagation conditions occur. The mobility of vehicle is not random because vehicles have predetermined paths in streets and roads. Due to this irregular connectivity the collision in wireless medium and frequent network fragmentation occur (Viriyasitavat, Bai, & Tonguz, 2011). The MANET nodes are slow but the VANET nodes are moving fast. The connection time between two vehicles is very short because the both vehicles moving with different speeds and the route maintenance can be hard. Special type of communication device equipped and attached with vehicles body in VANET. The function of these devices communicates with location information system and Global Positioning System (GPS), which are onboard sensors (Lemelson & Pedersen, 2002).In VANET the energy problem is not an issue because vehicles have sufficient energy for handle the equipments but in MANET still many challenges present relates with energy conservation . MANET has a major issue of energy and with limited battery power. On the other hand, the MANET scenario is much simpler and the nodes have freedom for movement. The MANET is a completely different in mobility with VANET.

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3. VANET Typical Road Situation

In Vehicular Ad-Hoc networks, there is a broad diversity of situations. However, we discuss the main two environments that are urban and highway environment where vehicles communicate with each other. When we compare the both situations, we see several differences in urban and highway environment and these differences have a major impact on the communication models. The fig. No. 1 shows, the urban and highway structure and environment.

Fig. No.1 Urban & Highway Environment

3.1 Urban Environment

The urban environment is congested and has different corners, junctions, houses, buildings, other infrastructures, and they affecting the signals propagation. Due to congested urban environment and obstacles, the vehicle position has a main fact for performance of communication between vehicles. Mobility pattern is different in urban environment and driver has many options for divert the vehicle or change the road as well (Zhang, Lakas, El-Sayed, & Barka, 2013). The vehicle speed is low in urban environments because the streets, corners, sharp turns etc are there. In rush hours, the packet loss and car density is high. Multi hop must use in urban areas due to frequent obstacles.

3.2 Highway Environment

Vehicles stay is long in highways and direction usually straight and we analyze the vehicles set are same for forwarding information. Another difference of highway is vehicle speed and normally vehicles maintained 120 km/h speed. The connection time between vehicles and access points are opposite direction and fixed access point decreases significantly.

4. Routing Protocols Strategies

The position based routing protocols are based on the information of geographical position of the vehicles. The nodes are selecting the best path for forward the data to the destination in vehicular Ad-hoc networks. Instead, the topology based routing protocols use IP addresses for identifying the routes. The topology based and position based protocols are two main classes in VANET. In this paper we discuss the position based routing for VANET and protocols for two environments. The position based routing protocols split into three characteristics forwarding, path selection and recovery (Bilal, Bernardos, & Guerrero, 2013).

4.1 Path Selection

The routing protocols use path selection but it is not mandatory for path selection, but it is an advantage. In urban environment the availability of leading the message to path is high due to one not aware with node density during the selecting the next hop. The well-known algorithm Dijkstra is use for path selection strategy in VANET. In this algorithm, the path between a source and destination nodes is calculate the source node, with intersection and junctions as the graph edges. This is called path-using Dijkstra.

4.2 Forwarding Strategies

Forwarding strategy is must for position based routing protocols for forward the packets to the destination. For forwarding, the most used approaches are greedy forwarding (Karp & Kung, 2000), greedy along the path strategy, restricted greedy and recovery mode strategies. The greedy approach sends the packets to the neighbor node, which is near with destination node. When any type of path is used, it referred to as greedy along the path approach. It is same like greedy approach but a little difference is that the nodes are on the selected path or road to next junction. The restricted greedy approach is bottleneck of communication because it mitigates the propagation problem in junctions. The communication is not traversing because of corners and obstacles. They are base on the presence of a priority node in the centre of the junction. The improved greedy strategy is only routes packets through vehicles travelling toward the destination. Another strategy is recovery-mode strategy widely used and use right hand rule to traverse graphs. When the forwarding node is closer to the destination node the algorithm switches back and node triggers the recovery strategy.

5. Position-based routing protocols

The position based routing in vehicular Ad-hoc network works on location service for find the geographical position of destination via sending node. Vehicle movement in vehicular Ad-hoc networks is usually limited in bidirectional movements controlled along roads and streets (Li & Wang, 2007) . The routing strategies are using geographical location information from traffic models and street maps. This service can be either reactive or proactive. The next section will illustrate the most applicable routing protocols and their comparison. The VANET protocols classify into six types such as topology based, position based, Geo cost routing, cluster based routing, broadcast routing, and delay tolerant routing. We focus connection oriented position based routing protocols of VANET in this paper. Below figure shows the taxonomy of position based routing of vehicular Ad-hoc networks.

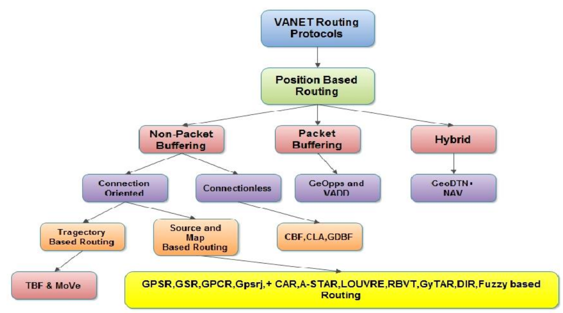

Fig No2 Classification of VANET Protocols

5.1 Geographical Source Routing GSR

The Geographical Source Routing (GSR) is a position based routing protocol and compute shortest path using Dijkstra Algorithm. The protocol also use GPS map information and greedy forwarding for employed along the pre -selected shortest path. The path consists of junctions that need to be transverse to reach destination. Geographical Source Routing protocol using greedy strategy, selects the vehicles for forwarding the packets to next junction, and repeats this action until the destination node reach. If in this process the vehicle is not available so then it selects other vehicle outside the road and still using greedy strategy (Lochert, et al., 2003).

5.2 Anchor-based Street Traffic Aware Routing (A-STAR)

The Anchor-based Street Traffic Aware Routing (A-STAR) protocol is a new position-based routing scheme. In this protocol, the term street awareness is a spatial awareness and more accurately use the street map information for anchor path. The protocol forward the data through calculation of a full path and different with GRS. The protocol uses the Dijkstra algorithm and sending node calculates the road path. It uses the greedy forwarding strategy along the path. Through sequence of junctions, the packet is passing to reach its destination. The G-STAR protocol computes the anchor paths with vehicular awareness (Seet, et al., 2004a, 2004b).

5.3 Greedy Perimeter Stateless Routing (GPSR)

Greedy Perimeter Stateless Routing (GPSR) routing protocol is a position based routing protocol and proposed for mobile Ad-hoc networks (MANET). GPSR protocol is best for packet delivery ration and low packet delay characteristics. The protocol uses two methods for forwarding the packets perimeter forwarding and greedy forwarding. The nodes in network have local table and table have the all neighbor nodes record their (ID) and position. The source node gives the packet a destination address and the address will not be change, and many more data listed. Node enters the recovery mode when none of the neighbor is closer to the destination and it is perimeter mode. The perimeter mode uses the right-hand rule. When the node having the packet is closer to the destination protocols return to greedy forwarding and when it entered recovery mode (Sunder Aditya Rao, Pai, Boussedjra, & Mouzna, 2008) .

5.4 Greedy Perimeter Stateless Routing with Lifetime (GPSR-L)

Greedy Perimeter Stateless Routing with Lifetime (GPSR-L) is a modification of GPSR protocol with the lifetime concept. The concept of lifetime timer is set for lifetime value. The timer helps for determining the quality link and duration of the neighbor as well. The protocol select the next hop which is closer to the destination and has a good link quality and non-zero lifetime timer value. This process is best in noisy and highly mobile environment. It is also decrease the packet loss. The overall performance is better compare to GPSR (S. A. Rao, Pai M.M, Boussedjra, & Mouzna, 2008).

5.5 The Greedy Perimeter Coordinator Routing (GPCR)

The Greedy Perimeter Coordinator Routing (GPCR) use greedy algorithm to forward packets and use the recovery mode. The problem of obstacles and junctions in VANET is a major problem in routing and these protocols solves the problem. The protocol is considering vehicles, which are middle in junctions. The Greedy Perimeter Coordinator Routing is also not calculating the path from source to destination and use greedy forwarding strategy but with some modifications such that it only routes messages along streets. The GPCR protocol does not account for low node density in selected streets (Bernsen & Manivannan, 2009).

5.6 Greedy Traffic Aware Routing (GyTAR)

Greedy Traffic Aware Routing (GyTAR) is a junction based position routing protocol and capable to find routes in city environment. In this protocol, the fixed routers are used in junctions for increasing the connectivity between nodes. The path is not constructed from source to destination (Jerbi, Senouci, Meraihi, & Ghamri-Doudane, 2007). The fixed node in junctions calculates the best next junction and taking into account the numbers of vehicles between them. The distance is also referred to curve metric distance toward the destination (Jerbi, Meraihi, Senouci, & Ghamri-Doudane, 2006).

5.7 Movement-Based Routing Algorithm (MORA)

Movement-Based Routing protocol is working with physical location of neighboring vehicles and their movement direction during selection of next hop for sending and forwarding packets. But we know in Vehicular Ad-hoc Networks the movement direction is not enough for next hop selection the speed also a important factor. The protocol uses flooding for destination discovery and sender includes its location information. When the destination will receive the request from source then it is generate a route reply message. MORA is use a routing metric that has the positioning and direction information (Granelli, Boato, & Kliazovich, 2006).

5.7 MOvement Prediction-based Routing (MOPR)

The protocol function is choosing a path by calculating the speed of the two neighbor's vehicles. The concept of protocol is getting better the routing process by selecting the steadiest route in term of lifetime and movement of vehicle. MOPR is based on vehicles movement information and select the best next hop for forwarding the data. The MPPR concept is based on vehicle movement prediction and estimates the stability of communication link in network lifetime and after this select the most stable route (Menouar, Lenardi, & Filali, 2007).

6. Applicability in Typical Road Situation

The applicability or routing protocols and vehicle mobility in urban and highway situation is different. These differences have a significant impact on performance of routing protocols. We discuss the properties for the routing protocols and adaptability in both scenarios.

The first property in urban environment is obstacles. The obstacle is a thing that blocks one's way, prevents, or hinders progress. In simple words it is a barrier between signals. Urban environment is congested and have a many obstacles. The routing protocol for VANET has a quality to provide mechanism to avoid obstacles. Due to transmission problem, the latency might be increase and decrease the accessibility due to packet failure. Therefore, the routing protocol has awareness to handle the obstacles. To overcome this problem the access points are install in junctions and corners. The urban environment is busy, some time the drivers can make abrupt turns and they are out of range. The routing protocol must be simple or maintain the nodes neighborhood update. Another property is speed and with less speed, the vehicles communicate with fix node for a sufficient time. The density of vehicle is high in urban areas. As a result routing overhead raise radically and low overhead protocol is use. Hence, the urban environment protocols are aware of obstacles, have no bottleneck, and do not use the full path strategy. On the other hand, the highway environment is obstacle less. The routing protocols ignore it and propagation condition is better. In highways environment the maintaining list of neighbors nodes updates and forwarding packets are better because of drivers can make few turns and there are some exit or entry points.

Table No. 1 Protocol Comparison of URBAN and Highway Scenarios

URBAN Environment								
Properties	**GSR**	**A-STAR**	**GPSR**	**GPSR-L**	**GyTAR**	**GPCR**	**MORA**	**MOPR**
Obstacles awareness	×	×	×	×	✓	✓	×	×
Street awareness	✓	✓	×	×	✓	✓	×	×
No bottleneck	✓	✓	✓	✓	×	×	✓	✓
No full path selection	×	×	✓	✓	✓	✓	✓	✓
Highway Environment								
No infrastructure	✓	✓	✓	✓	×	✓	×	✓
Neighbor direction (same)	×	×	×	✓	✓	×	✓	✓
Lifetime	×	×	×	✓	×	×	✓	✓
Carry-and-forward	×	×	×	×	✓	×	×	×

Table No.2 Simulation Parameters

Simulation	NS2.34
Testing Protocols	GPSR, MOPR, and MORA for highway environment
Scenario	400 Meters Length/3 Lanes
Vehicle Nodes	200
Minimum speed value	70 km/h
Maximum speed value	120 km/h to 210 km/h
Density between nodes	5 vehicles every 130 m
Standard	802.11 Medium Access Control (MAC)
Functions	Distributed Coordination Function (DCF) Carrier Sense Multiple Access with acknowledgments (CSMA/CA with ACK) Request-To-Send Clear-To-Send (RTS/CTS)
Traffic Type	CBR with 1024 Bytes of packet size and a 512 bps of maximum CBR rate
Performances metrics	Packet delivery ratio, delay, routing overhead, routing overhead ratio

The speed is high and due to this, the fixed access points are not use in highways and vehicle should only use vehicle travelling in the same direction as data to forward the packet. The node density and overhead is low. Thus, the routing protocols in highway environment not using infrastructure and use the neighbor's direction and concept of lifetime. Below table No 1 shows the both environments properties comparison.

7. Simulation and Results

We simulate the protocols in both urban and highway environments and evaluate which protocol is best for each environment. Firstly we take three protocols such as GPSR,MORP and MORA for highway environment. Below table is shows detail parameters for simulation scenario.

7.1 Protocol Simulation Results of Highway Environment

To assess the overall performance through NS2.34 simulation of three protocols in highway environment we create a highway scenario shows in Fig No.2 below. After that, we evaluate the three protocols GPSR, MOPR, and MORA for highway environment.

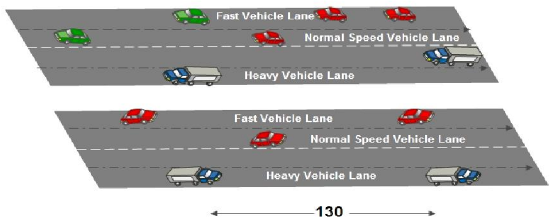

Fig No3. Highway Simulation Scenario

Figure 4 shows the Packet Delivery ratio (PDR) of three protocols and results shows that that MOPR protocol performance is better with other.

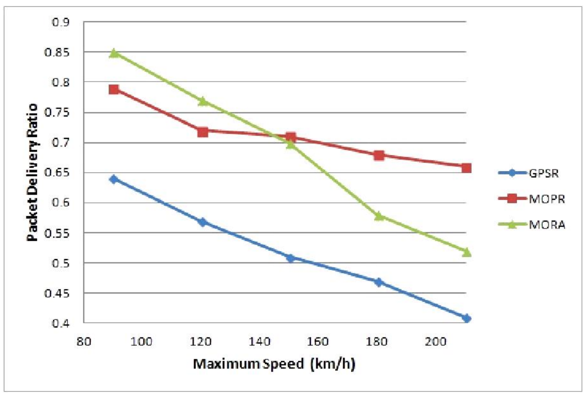

Figure No 4. Packet delivery ratio comparison of GPSR, MOPR, and MORA

Figure 5 shows the better performance of MOPR in delay of protocol.

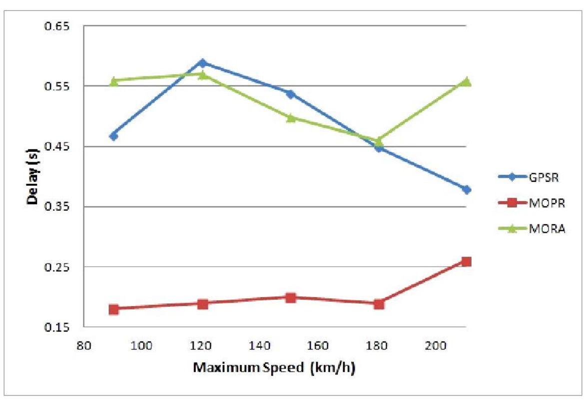

Figure No 5. Delay comparison of GPSR, MOPR, and MORA

Figure 6 shows again the good performance of MOPR in routing overhead when we compare with other two protocols.

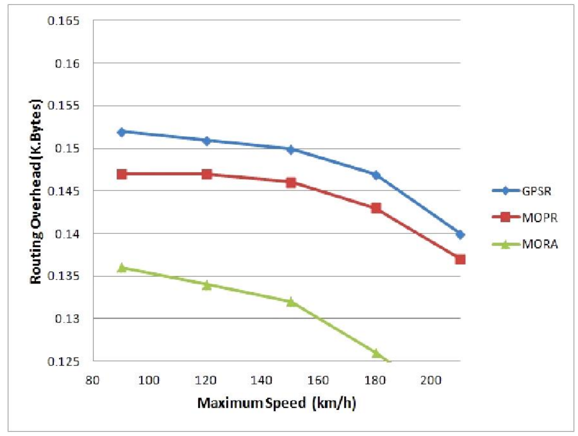

Figure No 6. Routing Overhead comparison of GPSR, MOPR, and MORA

Figure 7 shows again the best performance of MOPR in routing overhead ratio.

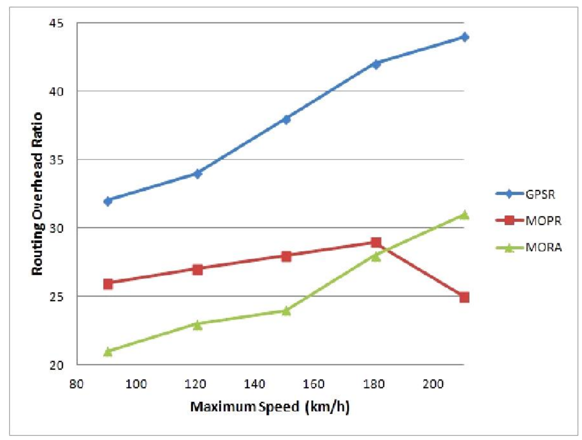

Figure No 7. Routing Overhead Ratio comparison of GPSR, MOPR, and MORA

We compare the three position based routing protocols in simulation and finally the results shows the better performance of MORP in different parameters. The MOvement Prediction-based Routing is better in packet delivery ratio, delay, routing overhead, ratio of overhead. Therefore, the result is that presently the MORP is a good choice in highway environment.

7.2 Protocol Simulation Result of Urban Environment

To assess the overall performance through NS2.34 simulation of three protocols in urban environment we create a highway scenario shows in Fig No.3 below. After that, we evaluate the three GPSR, GPCR, GyTAR Urban environment. Our simulation parameters are shown below in table No.3.

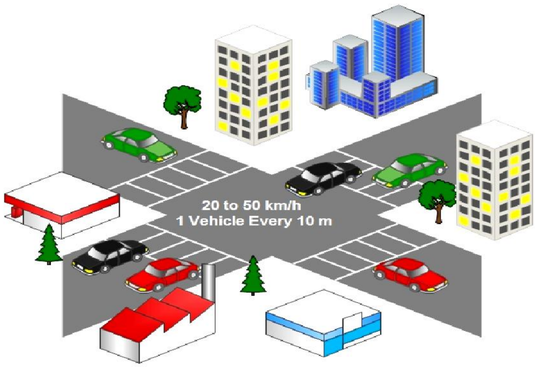

Fig No 8. Urban Simulation Scenario

Table No.3 Simulation Parameters

Simulation	NS2.34
Testing Protocols	GPSR, GPCR, GyTAR Urban environment
Scenario	300 total Area
Vehicle Nodes	20
Minimum speed value	20 km/h
Maximum speed value	40 km/h to 50 km/h
Density between nodes	1 vehicles every 10 m
Standard	802.11 Medium Access Control (MAC)
Functions	Distributed Coordination Function (DCF) Carrier Sense Multiple Access with acknowledgments (CSMA/CA with ACK) Request-To-Send Clear-To-Send (RTS/CTS)
Traffic Type	CBR with 1024 Bytes of packet size and a 512 bps of maximum CBR rate
Performances metrics	Packet delivery ratio, delay, routing overhead, routing overhead ratio

Figure 9 shows the GyTAR protocol performance in urban environment with high packet delivery ratio. The second best protocol is GPCR in urban environment.

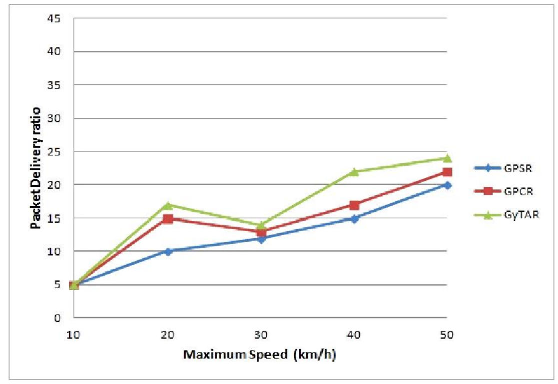

Figure No 9. Packet delivery ratio comparison of GPSR, GPCR, and GyTAR

Figure 10 shows the delay comparison of three protocols in urban environment and the results shows the good protocol is GyTAR in urban environment with low delay ratio.

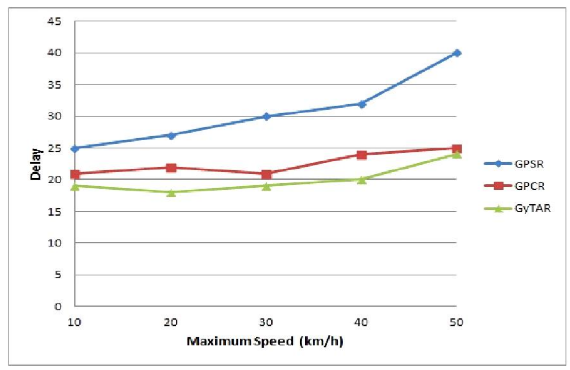

Figure No 10. Delay comparison of GPSR, GPCR, and GyTAR

Figure 11 shows the routing overhead comparison of three protocols, which are fit in urban environment. The graph show the GyTAR performance is good compare to other protocols and the overhead graph is low with other protocols.

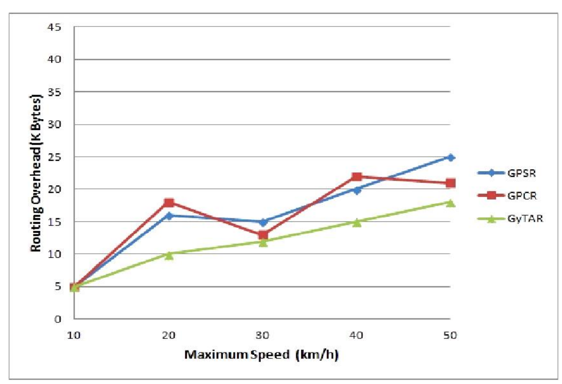

Figure No 11. Routing Overhead comparison of GPSR, GPCR, and GyTAR

Figure 12 shows the overall overhead ratio of three urban protocols and result shows the GyTAR is good in overhead ratio.

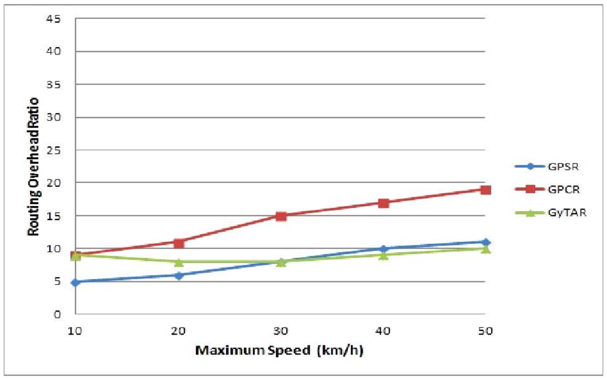

Figure No 12. Routing Overhead Ratio comparison of GPSR, GPCR, and GyTAR

We compare three position based routing protocols in urban environment through simulation. The results show the performance of three protocols in different parameters and in last we observed that GySTAR protocol performance is best and the second good protocol is GPSR in urban scenario.

Conclusion & Future Work

In this paper, we discuss the qualitative survey of position based routing protocols of vehicular Ad-hoc networks and surveyed recent several protocols. Vehicular Ad-hoc network is a special class of mobile Ad-hoc networks with our unique characteristics. We presented the detail comparison of VANET and MANET. We also discussed the different environments of vehicles network such as urban and highways environment and their characteristics between each other and we found they have different with each other by scenario. We elaborated the routing strategies such as greedy forwarding, greedy along the path strategy, restricted greedy and recovery mode strategies. We described different position based routing protocols, such as GSR, A-STAR, GPSR, GPCR, GyTAR, GPSR-L and MORA,MOPR. We compared these protocols based on urban and highway environment and we concluded that there is not a protocol for both environment. But currently the best one is GPCR, GyTAR for urban environment and for highway environment the GPSR and MOPR,MORA fulfill the requirement. The GyTAR is the less adequate.

The future work will develop a Hybrid protocol for urban and highway environment. That protocol will fulfill the requirement of routing in vehicular Ad-hoc networks.

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