

Geo-Reactive: An Efficient and Reliable Hybrid Routing Protocol for VANETs

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Abstract

Objective: The main objective of this paper is to find an efficient and reliable path for routing data packets in vehicular ad hoc networks using hybrid routing. The hybrid routing protocol, Geo-Reactive, comprises of geographical routing and reactive routing with stable links. **Method/Analysis:** An analytical model has been derived for selective forwarding of Route Request (RREQ) packets through stable links. The mobility trace is generated using SUMO (Simulation of Urban Mobility) tool. This trace file is fed to NS-2 (Network Simulator) to compare the performance of our proposed protocol with GPSR in terms of packet delivery ratio, packet drop ratio and end-end delay. **Findings:** The simulation results obtained have been compared with GPSR and the results were promising in terms of packet delivery ratio, packet drop ratio and average end-end delay. The packet delivery ratio of Geo-Reactive increases when compared with GPSR as packets are forwarded only through stable links. This avoids frequent link failures thus improving the packet delivery ratio. This is also reflected in packet drop ratio. In Geo-Reactive protocol the Sequence number in the packet header of the reactive phase ensures that packets never get into loops which forces packets to be dropped after the Time-To-Live (TTL) expires. Also reduction in frequent link failures reduces packet drop ratio. As Geo-Reactive establishes a path with stable links, end to end communication delay is also reduced. Thus Geo-Reactive outperforms GPSR. **Improvement:** Geo-Reactive protocol definitely improves the performance of position based greedy forwarding technique by adopting a reactive protocol with stable links as recovery strategy. This hybrid mechanism of forwarding data packets using stable links outperforms GPSR.

Keywords: Geographic Routing, Greedy Forwarding, Link Stability, Reactive Routing, Recovery Strategy, VANET

1. Introduction

Vehicular Ad Hoc Networks has wide spread applications in traffic management, traffic safety etc. For effective communication between vehicles and road side unit and among vehicles, VANET uses 802.11p WAVE (Wireless Access in Vehicular Environments) standard¹. Vehicular communication is used in Intelligent Transportation Systems (ITS) for ensuring safety and comfort.

Data dissemination plays a crucial role in the efficiency of ITS. Depending on the application, the requirements of vehicular networks vary. For safety applications, the messages delivered should have lesser delay and requires low bandwidth as safety messages are short messages whereas traffic management applications require

more bandwidth and are delay tolerant². Most of these messages are broadcast messages as information about safety applications are to be broadcasted to all the vehicles heading in a specific direction. Some of data disseminated might be unicast messages where data (audio/video) is exchanged between vehicles or between a vehicle and a hotspot with internet access which requires higher bandwidth and has higher delay tolerance. Effective delivery of these messages to one or more vehicles poses to be a great challenge owing to the dynamic nature of the network. This challenge can be overcome by choosing appropriate routing protocol to ensure data dissemination depending on the application³. Hence routing protocol plays an important role in data dissemination.

Routing protocol of VANETs can be broadly

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categorized into topology based routing and position based routing. Topology based routing can further be divided into proactive and reactive routing. In proactive routing, every node maintains route information about all other nodes in the network. The routing table is updated as and when there is mobility in the nodes⁴. Proactive routing is not preferred for VANETs as these networks are characterized by frequent changes in the network. Highly dynamic network leads to frequent update of the routing table making proactive protocols unsuitable for VANETs⁵. In contrast to proactive routing, reactive routing does not maintain routing table. It discovers the route as and when needed and maintains that route till message has been delivered at the destination. The route set up time in reactive protocols is more than that of proactive as it has to find route on demand. The main disadvantage of reactive protocol is that as VANET is susceptible to frequent link failures, route set up takes more time, which hinders the process of finding and maintaining the complete route. Hence topology based routing is found unsuitable for VANETs.

Position based routing does not depend on the network topology⁶. On the other hand it requires additional information about the position of every node in the network. Hence a location service is needed⁷. This location information can be obtained using a global navigation system such as GPS. Location based protocols maintain only neighbour information rather than the entire route. This reduces the large volume of control overhead involved in route discovery and route maintenance. Hence position based routing is more suitable for large scale ad hoc networks. Several communication schemes in ad hoc network that use GPS information for data dissemination are discussed in⁸⁻¹¹.

Most of the geographic routing follows greedy approach which has two disadvantages: Packets caught in loop and void region. The greedy protocol should ensure that route followed by the neighbouring nodes is loop free. This can be achieved using packet sequence number and/or TTL (time to live) for any packet. When an intermediate node has no neighbour to forward the packet towards the destination, it is said to be in void region or local maximum. Several recovery strategies have been discussed to overcome the local maximum.

This paper proposes a hybrid routing protocol comprising of geographic and reactive routing. The proposed protocol initially follows greedy forwarding approach. In the greedy mode, whenever a local maxima

is encountered the protocol switches to reactive mode. In the reactive mode, a route discovery is made on demand based on link quality and packets are forwarded in the established path. For every hop in the reactive mode the intermediate node checks for possible greedy forwarding and if available switches to greedy mode.

Most of the routing protocols in VANET employ position based greedy routing for effective communication as they do not require a route to be established and maintained between the source and destination. Each node decides the forwarding node as and when a packet arrives based on its current neighbours and chooses the node that is closer to the destination. The main drawback of greedy routing is that at times there may be no node that is closer to the destination rather than itself. All the greedy protocols have a strategy to come out of the void region. Hence every greedy protocol has a recovery strategy associated with it. This combination of greedy forwarding with appropriate recovery strategy proves to be effective in vehicle - vehicle communication because of less overhead and quicker route convergence. This section analyses the recovery strategies followed by various greedy routing protocols as well as the advantage of reactive protocols.

1.1 Recovery Strategy in Geographic Routing Protocols

The Greedy Perimeter Stateless Routing protocol (GPSR)¹² routes data using greedy forwarding technique. If greedy routing fails due to local maxima then it follows right hand perimeter rule to route data till it encounters a greedy forwarding node. The right or left hand perimeter rule ensures that no loop is formed. The recovery strategy of Greedy Perimeter Coordinator Routing (GPCR)¹³ is similar to GPSR but avoids planarization as the road topology naturally forms a planar graph. GPCR differs from GPSR by forwarding the packets in a greedy fashion on the street and at junction the coordinator node decides on which street the packet should be forwarded. Enhanced perimeter routing for geographic forwarding protocols in urban scenarios (GpsrJ+)¹⁴ improves the recovery strategy of GPSR and GPCR. GpsrJ+ enhances the performance of GPCR by predicting the route that a junction node will follow to forward the message and forwards the message through that route by bypassing the junction node wherever possible. Greedy Traffic Aware Routing (GyTAR)¹⁵ follows carry and forward mechanism

as recovery strategy till a greedy forwarding node comes into its transmission range. Position Based Routing with Distance Vector (PBR-DV)¹⁶ uses AODV protocol as recovery mechanism when packets encounter local maximum. PBR-DV broadcasts the current node location and destination location to establish a new route. At every hop the node checks for possible greedy forwarding neighbours towards the destination and if found switches to greedy mode. In Contention Based Forwarding (CBF)¹⁷ the neighbour selection is done by the forwarding nodes rather than the current node. Optimal forwarding path and restricted forwarding algorithm is used as recovery strategy to overcome the local maxima in¹⁸.

1.2 Reactive Protocols

As explained earlier reactive routing protocols does not maintain neighbour table. Hence the huge control overhead incurred in proactive routing protocols to maintain neighbour table information is eliminated in reactive protocols. This results in lesser overhead. Reactive protocols have three phases namely: Route Request, Route Reply and Route Maintenance. Routes are established on demand. In Dynamic source routing¹⁹ the source node initiates the route request. As the path length increases, overhead also increases. No stale routes in AODV²⁰ as against DSR due to the destination sequence number included in the request packet. TORA²¹ ensures loop free routing with lesser overhead in case of link failures using link reversal algorithm. ABR²² provides on demand stable routes based on the number of beacons received by a forwarding node. Several reactive protocols have been discussed in²³ and has been concluded that reactive protocols are highly suited for frequently changing mobile networks.

In order to design an efficient and reliable protocol with higher throughput and less control overhead, we propose to use the best of these categories of protocol namely geographical and reactive. We propose a novel hybrid protocol which uses greedy approach to route data packets and uses a reactive mechanism as recovery strategy to overcome the local maxima problem.

2. Proposed Protocol

In this paper we propose a novel hybrid routing protocol namely Geo-Reactive which aims at providing efficient and reliable route. This is achieved by incorporating greedy

forwarding method initially and when the greedy method encounters local maxima, it switches to on demand routing. In PBR-DV¹⁶ the authors have used AODV, a reactive protocol, as recovery mechanism. This ensures that the shortest path between the local maxima node and destination is established. But PBR-DV is susceptible to frequent link failures due to high mobility. This leads to frequent path set up and more control overhead.

2.1 Assumptions

- Every vehicle is equipped with GPS.
- The beacon packet comprises of a node's location and velocity.

Our main contribution in this paper is to improve the performance of the reactive protocol used as recovery strategy. This is achieved in two phases.

- In reactive routing protocols route request packets are forwarded to all neighbouring nodes till a path is established. This induces more control overhead. Instead we propose to forward the route request packet only to neighbouring nodes which reside in the positive direction towards the destination. This reduces the amount of control overhead incurred.
- While forwarding the request packets every node will attach its link stability status to the packet header. This helps the destination node to set up a stable path rather than the shortest path which is prone to frequent link failures.

2.2 Selective Packet Forwarding

In this phase our protocol makes use of the location information available with the help of GPS. If (x_{in}, y_{in}) and (x_d, y_d) are the location coordinates of the intermediate node, which has encountered the void region and the destination node D, then the distance ($dist_{in-d}$) between them is given by,

$$dist_{in-d} = \sqrt{(x_d - x_{in})^2 + (y_d - y_{in})^2} \quad (1)$$

Given the velocity \bar{V}_{fn} and \bar{V}_{mn} of intermediate node I1 and its neighbour node(s), their vector representation is given by,

$$\bar{V}_{fn} = V_{fn_x} \hat{x} + V_{fn_y} \hat{y} \quad (2)$$

$$\bar{V}_{mn} = V_{mn_x} \hat{x} + V_{mn_y} \hat{y} \quad (3)$$

The dot product of the vectors \bar{V}_i and \bar{V}_n results in a scalar quantity.

$$\vec{V}_{fn} \cdot \vec{V}_{mn} = V_{fn_x} V_{mn_x} + V_{fn_y} V_{mn_y} \quad (4)$$

Equation (4) yields a positive value if the two vectors travel in the same direction and a negative value if they travel in opposite directions.

The above equation can be rewritten as,

$$\vec{V}_{fn} \cdot \vec{V}_{mn} = |V_{fn}| |V_{mn}| \cos\theta \quad (5)$$

Angle between the two velocities \vec{V}_f and \vec{V}_n is given by,

$$\theta = \cos^{-1} \frac{\vec{V}_{fn} \cdot \vec{V}_{mn}}{|V_{fn}| |V_{mn}|} \quad (6)$$

The intermediate node I1 initiates Route RRequest Packet (RREQ). The RREQ packet has the sequence number, destination ID, position of I1 and D, distance ($dist_{id}$), velocity of I1 and link status ($link_state_{in}$). The velocity information in the beacon packet is used by the intermediate node I1 to selectively forward the RREQ packet to only those neighbours whose relative velocity is definitely positive as given by Equation (4). This ensures that RREQ packets are forwarded only to those neighbours who travel in the same direction. Thus unnecessary control overhead incurred in the form of broadcasting the RREQ is avoided.

2.3 Selection of Stable Path

While selectively forwarding the RREQ packet to its neighbours the forwarding node updates the link status between itself and its neighbour.

Given the velocity \vec{V}_{fn} and \vec{V}_{mn} of intermediate node I1 and its neighbour node(s), and the time taken as Δt the distance travelled is given by,

$$d_{fn} = \frac{\vec{V}_{fn}}{\Delta t} \quad (7)$$

$$d_{mn} = \frac{\vec{V}_{mn}}{\Delta t} \quad (8)$$

The magnitude of the relative velocity of intermediate node (f) and its neighbour (n) is given by,

$$VREL_{fn} = \sqrt{(V_{fn})^2 + (V_{mn})^2 - 2V_{fn}V_{mn} \cos\theta} \quad (9)$$

If the transmission range of the forwarding node is t_r , then using law of Cosines, t_r can be represented as,

$$t_r = \sqrt{(V_{fn}\Delta t)^2 + (V_{mn}\Delta t)^2 - 2V_{fn}V_{mn}\Delta t^2 \cos\theta} \quad (10)$$

$$\Delta t = \frac{r}{\sqrt{V_{fn}^2 + V_{mn}^2 - 2V_{fn}V_{mn} \cos\theta}} \quad (11)$$

Substituting Equation (9) in Equation (11), we get,

$$\Delta t = \frac{r}{VREL_{fn}} \quad (12)$$

Δt is the elapsed time of two nodes moving with a velocity of V_{fn} and V_{mn} . This also indicates the link lifetime (LLT). Hence LLT is given by,

$$LTT = \frac{r}{VREL_{fn}} \quad (13)$$

If the two vehicle nodes move in parallel then the angle = 0 which reduces the Equation (9) and Equation (13) becomes,

$$LTT = \frac{r}{||V_{fn} - V_{mn}||} \quad (14)$$

Hence from Equation (14) we can infer that as long as the difference between the two velocities is minimum ($> = t_r$) LLT is stable.

The LLT calculated using Equation (14) is sent as link status to the neighbouring nodes by the forwarding node. Each forwarding node forwards the RREQ packet to its neighbours whose LLT is greater than t_r . Thus the RREQ packet received by the destination node D has list of nodes whose LLT is stable. The RREP packet is sent via the shortest path out of multiple paths available. DATA packets are sent through the shortest stable path. This ensures minimal link error and control overhead.

Each DATA packet forwarding node in the reactive path checks for greedy forwarding approach and if found available switches to greedy technique. The process of switching back and forth between greedy and reactive continues till the destination node D is reached.

3. Results and Discussion

To assess the performance of our proposed protocol, we have conducted a set of simulation experiments to

compare the performance of existing protocols under realistic environment.

3.1 Simulation Setup

The traffic scenario is generated using SUMO (Simulation of Urban Mobility) with varying density of vehicles. The mobility trace from SUMO is fed to Network Simulator - 2⁴.

The simulations were done in a two lane grid topology of size 1000m x 1000m with varying vehicle densities of 20, 40, 60, 80 and 100. The speed of the vehicle varies between 40km/hr to 80km/hr. The propagation model used is two-ray ground propagation model with a transmission range of 250m. The transmission rate of the data packets is at the rate of 5packets/s. The size of the data packet is 512 bytes. The simulation runs have been carried out 8 times for a period of 100s/ simulation and the average values were used to represent performance of the proposed protocol.

3.2 Analysis of Results

Different performance metrics such as packet delivery ratio, packet drop ratio and average end-end delay are calculated to prove the performance of our proposed protocol.

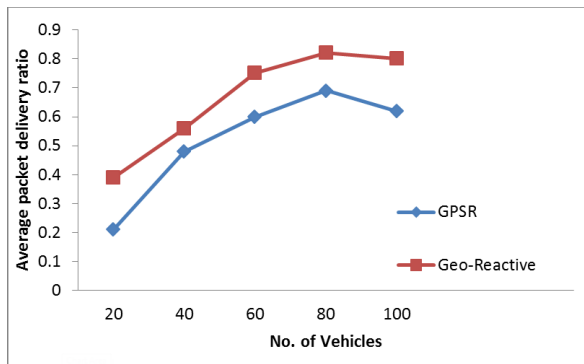


Figure 1. Packet delivery ratio.

Figure 1 shows the Packet Delivery Ratio of GPSR and Geo-Reactive for varying vehicle densities. We see that the packet delivery ratio of our protocol outperforms GPSR. This is due to the fact that link failures and loops encountered in GPSR are minimized in Geo-Reactive. Also it is found that as vehicle density increases PDR of GPSR reduces due to high mobility whereas our protocol maintains the PDR.

Figure 2 shows the packet drop ratio of GPSR and Geo-Reactive under varying vehicle densities. As the density of the vehicle is less frequent disconnections take place leading to packet drops in GPSR. Geo-Reactive also shows packet loss at low density but as the density improves the number of packet drops is very less whereas in GPSR the dropped packets are high when compared with our protocol. This is due to frequent link changes in GPSR leading to packet drops.

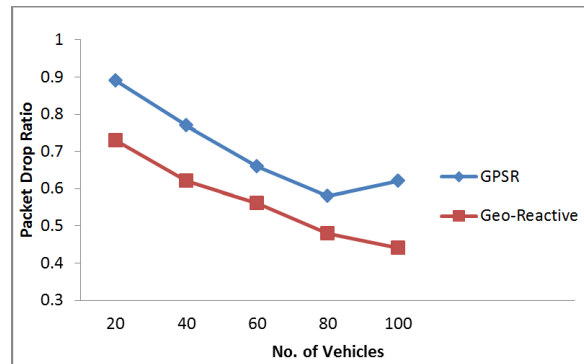


Figure 2. Packet drop ratio.

Figure 3 shows the average end to end delay. The delay incurred in Geo-Reactive protocol is very less when compared with GPSR. This is achieved through stable links in the reactive mode. In GPSR, more time spent in perimeter mode results in more hops thereby delaying data delivery. Our protocol ensures delay is kept minimal by maintaining a stable link which reduces retransmission improving data delivery in minimal time possible.

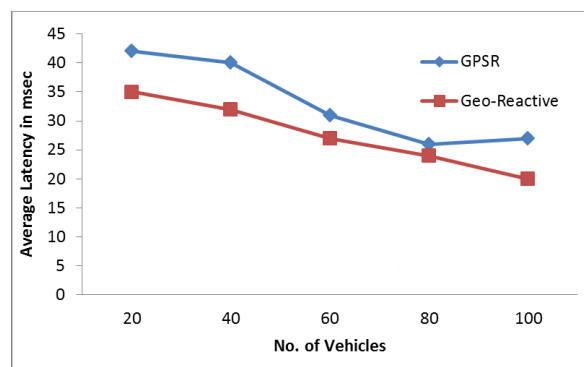


Figure 3. End-end delay.

4. Conclusion

A novel hybrid protocol comprising of greedy and reactive mode with stable path is proposed and simulation results

are shown. Our protocol overcomes the problem of loops encountered in GPSR by adopting reactive approach with stable link. This is made possible by selecting forwarding nodes with stable links and also the control overhead is minimized by forwarding the packets to only those vehicles which are travelling in the same direction. Our simulation results show that GEO-Reactive outperforms GPSR in terms of packet delivery ratio, average end-end delay and packet drop ratio.

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