Network and Complex Systems
ISSN 2224-610X (Paper) ISSN 2225-0603 (Online)
Vol.3, No.9, 2013
www.iiste.org

A Qos Adaptive Routing Scheme (IGLAR) For Highly Dynamic Vehicular Networks with Support to Service and Priority

Pooja Bhatt
M.E. (CSE) Student,
Parul Institute of Technology
Vadodara, Gujarat, India
E-mail: bhattpooja.393@gmail.com

Rohit Srivastava
M.Tech (CSE)
Parul Institute of Engineering &Technology,
Vadodara, Gujarat,India
E-mail: rts_09@gmail.com

Abstract

This paper proposes an improved geolocation based QoS aware routing algorithm (IGLAR), which focuses on identifying optimal paths for effective routing in highly dynamic mobile ad hoc network such as VANET based on vehicular traffic at cross roads over a static high way lane. The process of selection and utilizing the optimal QoS route gets updated on transmission. IGLAR works on route identification, route binding, update and deletion process based on the validation of adaptive QoS metrics, before the optimal route selection process between source and destination. This research work discusses on the survey and analysis the performance of GPSR [9], AODV [8], DYMO [12] and proposed scheme based on simulation test beds and scenario mapping using VanetMobiSim with NS-3 simulator. The proposed routing scheme IGLAR has been designed and implemented as per the DSRC specifications [13] and IEEE 802.11p MAC.

Keywords: VANET, GPSR, AODV, DYMO, VanetMobisim

1. Introduction

A QoS aware adaptive routing algorithm (IGLAR) is proposed in this research paper which focuses on optimal path identification for effective routing over a highly dynamic mobile ad hoc network such as VANET. Traditional routing protocols such as GPSR, AODV does not focus on vehicle traffic behavior at any cross roads or junctions. Hence the need for a routing protocol to handle geospatial location of a vehicle and control heavy traffic intensity is required. The process of selection and utilizing the optimal QoS route gets updated on transmission. IGLAR works on route identification, route binding, update and deletion process based on the validation of adaptive QoS metrics, before the optimal route selection process between source and destination. The research work elaborates on survey and analysis the performance of GPSR [9], AODV [8], DYMO [12] and proposed IGLAR based on simulation test beds and scenario mapping using ns2 simulator. The proposed routing scheme IGLAR has been designed and implemented as per the DSRC specifications and IEEE 802.11p MAC.

The objective of IGLAR focuses on:

[a] Major challenge in protocol design in VANET is to improve the reliability of routing data with support to reduce delivery delay time and minimize the number of packet retransmission.

[b] Abstract vehicular mobility is one of the major issue that leads to delay, hence designing of delay bounded routing protocols is also a challenge, since multicast carry and forward is an approach to deliver packets.

[e] Priority for vehicles such as patrol, ambulances, VIPs which require safe transit on a highly congested road,

which is considered in this research.

To analyze the performance of IGLAR two different urban road scenarios were considered as discussed in Section-4. Real time road traces were created with VanetMobiSim [14] which can work on NS-3 simulator [15]. The scenario maps consider varying speed of vehicles, vehicle priority, and service priority, cross road intersections, lane information and traffic intensity on road at varying time intervals. The simulated results show that IGLAR protocol's performance is found to be better than protocols surveyed in Section-2 for both the studied scenarios. Performance of metrics such as successful data delivery, average delay, had been studied.

2. Review Of Literature Work

Position based routing protocols such as LAR, DYMO, GPSR requires prior knowledge of geographic location information of vehicles (from a GPS service) could be applied in VANETs for faster route information and performance. It had been noticed that position based routing protocols also suffer from severe geographic routing failures due to presence of "topology holes". The authors propose spatially aware routing to overcome such drawback. But the effectiveness in optimality of spatially aware routing could not be judged due to spatial non-awareness. Hence it could be proved and it could be further enhanced in order to improve performance.

An epidemic routing approach for VANET with tolerance support for delay. In sparse vehicular traffic, opportunistic forwarding mechanisms would be helpful for vehicle–to– vehicle ad hoc communications. AODV routing protocol is dynamic in identifying route based on driver behavioral parameters. This scheme had been simulated using VanetMobiSim [14] over NS-3[15], with support for real time road scenario. The major drawback of this AODV is that it lags in maintaining route delay which is one of the major requirements of media streaming services in support of QoS.

The IGLAR protocol also supports applications which are not necessarily delay tolerant. IGLAR routing protocols works on maintenance of an end to end path for streaming media data to reach its destination.

Receiver based hop selection is proposed at routing layer for most of the routing protocols or at MAC layer. The debate on which method is better is dependent on the performance of protocol in minimizing the effective end to end delay. Measures to minimize the hop distance between the source node and its neighbor node were considered as one of the problem objective in, where hop decision is taken at the MAC layer. Proposals research on methods to improve route recovery strategies by proactively identifying potential dead end positions on a route or using channel overhearing capabilities of wireless networks to reduce the number of hops on the recovery paths.

Discusses on transmission methods where all neighbors can receive the entire packet, while any one neighbor can re-broadcast. This broadcast neighbor is selected based on time-based contention phase in which a node closest to the destination is considered. Geographical routing protocols, such as GPSR, GPR, require geographical node positions to route data between end-points. Once the local maxima is achieved, the algorithm stops since a new position is achieved and progress cannot be made based on node positions, which attributes to major failure.

The need for optimal, route aware adaptive routing protocol is required which can be designed and implemented based on vehicular mobility metrics, road map scenario. Hence IGLAR focuses on these issues as primary metrics as well provide QoS on demand for variable services on mobility.

3.IGLAR (QOS Adaptive Routing Scheme)

IGLAR design and simulation is primarily based on the vehicular behavior and communication model. The ns-3[15] simulations initially carried out over IEEE 802.11 for VANET shows the performance of wireless medium to be congested, due to overhead of periodic "hello" packets, which also degrades the performance of end-to-end data transfer.

IGLAR proposes a beaconless, distributed, receiver-based next-hop selection routing protocol to minimize this overhead, since VANET adopts non-uniform radio propagation. IGLAR introduces a simple modification of RTS/CTS mechanism in IEEE 802.11 standard. To identify the next best hop, an optimal multi-criterion prioritization function is adopted, using parameters as distance between each next hop and the destination, bandwidth required, received power level (which could be affected by noise and channel fading) and distance to transmitter.

IGLAR proposes two schemes of route connection between source and destination, based on radio propagation, (a) Connectivity between RSU and Vehicles (V2I), (b) Vehicle to vehicle (V2V). Since the intensity of nodes at cross-roads is higher, a RSU can help in maintaining the route between VANET nodes. The bandwidth of RSU can be shared between nodes at an instant; hence demand on QoS is controlled. While VANET nodes on a high way road or lane may be high mobility the challenge lies in catering to demand on QoS.

3.1. Modeling IGLAR

IGLAR is modeled as a set of high speed vehicles on a straight highway in which any vehicle can establish connectivity with any other vehicle(s) traveling in same direction or opposite direction of its motion. Vehicles within the communication range can help in forwarding the data to be transmitted between the source and destination.

Here IGLAR assumes the highway road R consisting of L lanes and connected to C number of cross-roads. Speed is not defined on the lanes as adopted in DYMO, hence any vehicle can cross another vehicle during its transit, hence it is assumed that each lane Li has variable speed limit Si. Each vehicle can communicate with another vehicle (in same direction or opposite direction), once the vehicle comes within communication range as per DSRC standards.

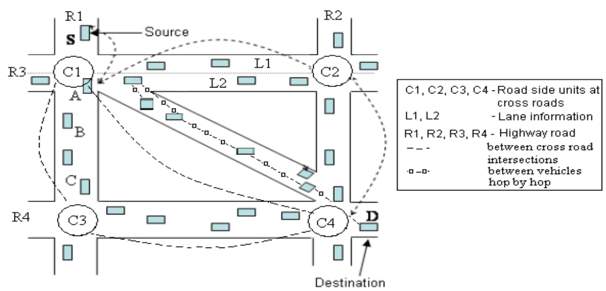

Figure 1- Design of IGLAR on a highway road scenario

Highway Road – Ri

Lanes in road- Li

Cross Roads – Ci

Speed of Vehicle – [Vi, Si]

Service priority – [Vi, Se]

Vehicle priority – [Vi,Pi]

The traffic intensity of vehicles at any instant of time – t, where t can be gathered at any Ci or Ri or Li.

The intensity of vehicles on road or between lane(s) determines the fairness of providing the QoS on demand. As IGLAR adopt DSRC standard, IEEE 802.11 MAC is considered at link layer communicating at 5.9 GHz frequency. The RSU nodes at cross roads control the intensity of vehicular traffic over periodic intervals of time. Connection established between the source ‘S’ and destination or receiver ‘D’ can be provided as hop-by-hop connection using forwarding nodes ‘Fi’ or using nodes at cross road ‘Ci’. Any ‘Ci’ can maintain the identity of vehicles within its radio communication range, as well can communicate with its neighbor ‘Cj’ or ‘Ck’. Vehicles can be classified as Source node ‘S’ or destination node ‘D’, and to forward data during transit as forwarding node ‘Fi’.

3.2. IGLAR metrics

[a] ∂ - Radio propagation intensity of nodes.

[b] η - Delay between hop

[c] α - End to end delay

[d] δ - Packet loss (between source nodes and destination in bytes)

[e] σ - Link capacity of transmitting nodes

[f] ε - Average throughput at receiver

[g] τ – Route /hop identification wait time

[h] ρ - Service priority

IGLAR metrics are primary to identify the optimal QoS on demand for various type of services between differing nodes in communication. The following assumptions are adopted for any route to be optimal.

[a]'α' is a major parameter to define an optimal QoS, only if a set of forwarding nodes between source and destination 'η' would be minimal (<0.1ms) and number of hops (H) would be ¬1.

[b] A VANET node 'i' is considered to be within the communication range of its neighboring node 'j' only when '∂'of i is acceptable within ∂ of j or an RSU. At any time't', VANET nodes are assumed to be distance'd' apart. If'd' is large, then nodes may not be able to communicate with each other, instead intermediate forward nodes are required for connection establishment.

Hence always 1<=di, j (t) < α, since 1 is the minimal distance assumed between nodes i, j.

[c]Two nodes 'i' and 'j' remain connected for a period of time't', until the range lies between [1, α], else disconnected. This also signifies the mobility speed of vehicles such that di, j (t) is dependent on S [i, j].

[d] A route is considered to be optimal when ε is > 1, being dependent on α <1ms, δ lies between [0, 0.9] as well dependent on τ andρ, which minimizes delay.

3.3. IGLAR procedure

Three major functionalities are carried out by a generic adhoc routing protocol, such as discovery of new route, selecting an optimal route (from multiple valid routes available), perform route maintenance for transfer of data during transit and route update. IGLAR also adopts the following route management procedures for providing the required QoS. Route Creation and Route Maintenance, Route Update and Optimal Route Selection (Route IGLAR_OPR) using two procedures (discussed in Section 3.4 and 3.5).

IGLAR works on route creation process, where a route created is considered OPTIMAL, only if it can satisfy the required IGLAR QoS metrics (discussed in Section-3). If an optimal route has been identified from a source to its destination and selected, then route maintenance procedure should be carried out to monitor the session in use.

Latency issues such as packet loss, session breakout, link failures (due to location change in forwarding nodes), delay (due to increase in number of hops) leads to implementation of route re-discovery procedure which selects the next optimal route available such that QoS is maintained for the session. Route maintenance procedure and re-discovery process involve extensive signaling and computation methods. Hence the desirable option is to select the optimal route with links of maximum possible lifetimes during the optimal route selection phase.

Route optimality posses a higher priority along with link delay, since it is more vital for the route quality in vehicular environments. The primary principle is that reliable routes that have longer expected lifetime and less hop numbers should be chosen instead of the shortest paths which may probably break soon and introduce high maintenance overhead. By taking this approach, the authors aim to significantly reduce the routing overhead, and improve the traffic throughput of high speed vehicles in VANET.

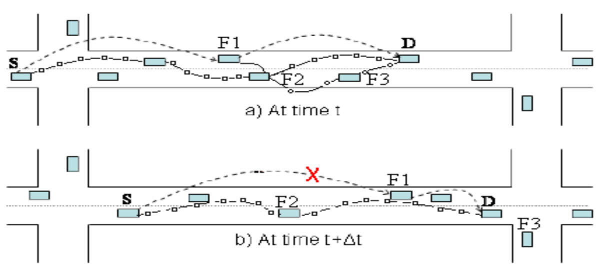

Figure 2- Vehicle to vehicle communication at different time intervals

(a) At time 't', Route [S,F1,D] and alternate route [S,F2,F3,D]

(b) At time 't+Δt', Route [S,F2,D], which is an Optimal route due to failure of Route [S,F1,D]

3.4. Procedure 1 {Route Create (Route_Id, Route Next, Qos_Value)}

Route Request (IGLAR_REQ) and Route Reply (IGLAR_RPL) at any node Fi

Variables:

S, D: Identity of source and destination VANET nodes

Route [ ]: Array route consisting of all temporary VANET nodes

Route_OPT, TempRoute: Optimal route and temporary routes from S to D

z: Vehicular priority

| Hopk |: 'k' number of hops between S to D, where 'k' being the radio propagation length

Ri (Li, Fi): Road segment with Lane segment where VANET node Fi is located

Ci = Cross-road route

τ: Route update Time Wait (TW) parameter

IGLAR_REQ : Route request packet

IGLAR_RPL: Route reply packet

IGLAR_OPT: Optimal Route

Upon receiving IGLAR_REQ (S, D, TempRoute) from any Fi

1: if (S == D) & (|TempRoute| Î Route) then

2: Route_OPT = TempRoute

3: Send IGLAR_RPL(S, D, Route_OPT)

4: return

5: else

6: send IGLAR_RER (0)

7: end if

8: if IGLAR_REQ = θ

9: if (Ri (Fi) ≠ Ri (Fj)&(Ri(Fi) Ì TempRoute) then

10: add Ri (Fi) to Route [ ]

11: end if

12: set Hop k = distance (Fi, Fj) τ

13: increment Hop k

14: endif

15: if Ri(S) == Rj(D) then

16: stop Hopk /* Fi is a better broadcast node*/

17: end if

18: set t = 0

19: IGLAR_BCS Route (S, D, TempRoute) /* broadcast route */

20: receive IGLAR_RPL (D, S, Route_RPL (Fj-1, Fi-1, -1)) from Fj

21: if t ≠ -1 then goto step 8

22: else

23: continue

24: if (Fi == S) then

25: store Route_RPL in Ci

26: forward IGLAR_REQ (S, Fi, ROUTE_RPL (Fi+1, Fj+1, D,z))

27: end if

3.5. Procedure 2 {Route Optimal Discovery and Route Update}

Identifying an optimal route for a service between source and destination defines the process of satisfying the QoS on demand as per IGLAR metrics. Any service can be effectively accomplished if a best possible route or an optimal route among the available links is selected. The "capability" of defining an optimal route is based on the communication effectiveness for expected service in terms of fuzzy measure.

Any node or link which is not "capable" to communicate as per optimality condition is defined as Worst.

Optimization helps in providing an adaptive service for services which demand QoS consistently such as Streaming media delivery, content management feed, media conference. Optimization is provided (a) assigning route with required bandwidth, (b) maintaining and monitoring IGLAR metric ton delay, packet loss, no of hops, radio propagation range.

IGLAR_OPR(NodeID_send(j),NodeID_recv(j), IGLAR_metric, Link_ID(j), z, μ), where j is set of route links identified between 1 to n

Variables:

S, D: Identity of source and destination VANET nodes

Route [ ]: Array route consisting of all temporary VANET nodes

Route_OPT, TempRoute: Optimal route and temporary routes from S to D

z : Vehicular priority

μ: Service priority

|Hopk|: 'k' number of hops between S to D, where 'k' being the radio propagation length

Ri (Li, Fi): Road segment with Lane segment where VANET node Fi is located

Ci = Cross-road route

τ: Route update Time Wait (TW) parameter

IGLAR_REQ : Route request packet

IGLAR_RPL: Route reply packet

IGLAR_OPT: Optimal Route

Upon receiving IGLAR_REQ (S, D, TempRoute) from any Fi

1: if ((S == Fi) || (D==Fj)) & (|TempRoute| Î Route [ ]) then

2: Route_OPT = TempRoute

3: send IGLAR_RPL(S, D, Route_OPT)

4: return

5: else

6: send IGLAR_REQ(S, D, TempRoute, μ, z)

7: set Hopk = distance(Fi , Fj) τ /* hop count between nodes */

8: set z = High || Low || Normal

9: set μ = High || Low || Normal

10: set t = 0

11: if IGLAR_OPT = θ

```
12: if ( Ri ( Fi ) ≠ Ri ( Fj )&( Ri(   Fi )    ÌTempRoute) & IGLAR_REQ (Fi+1,Fj+1, µ) then
13: add Ri (Fi) to Route_OPT /* add the best route to Optimal Route */
14: end if
15: increment Hopk
16: if RI (S) == Rj (D) then
17: stop Hopk                                    / * Fi is a better broadcast node */
18: end if
19: send IGLAR_OPT (S, D, TempRoute,z) /* Optimal route */
20: receive IGLAR_RPL (D, S, Route_RPL (Fj-1, Fi-1, -1)) from Fj
21: increment IGLAR_OPT
22: if t > 1 then goto step 10
23:   else
24: continue
25: endif
26: if (Fi == S) then
27: store IGLAR_OPT in Ci and Ri
28: forward IGLAR_REQ (S, Fi, ROUTE_RPL (Fi+1, Fj+1, D,z))
29: end if
30: endif
```

The step by step explanation of the algorithm is discussed in this section. Steps 1 to 6 explains the optimal route identified if the route is found to be shortest between the source and destination, with no other possible routes found in TempRoute list. Step 7 to 10, assigns default values for IGLAR_OPT metrics, Step 11 checks whether an optimal route is available in list IGLAR_OPT, else the process of adding the possible links based on the service request is added to IGLAR_OPT as explained in Step 12 to 14.

3.6. Message Flow

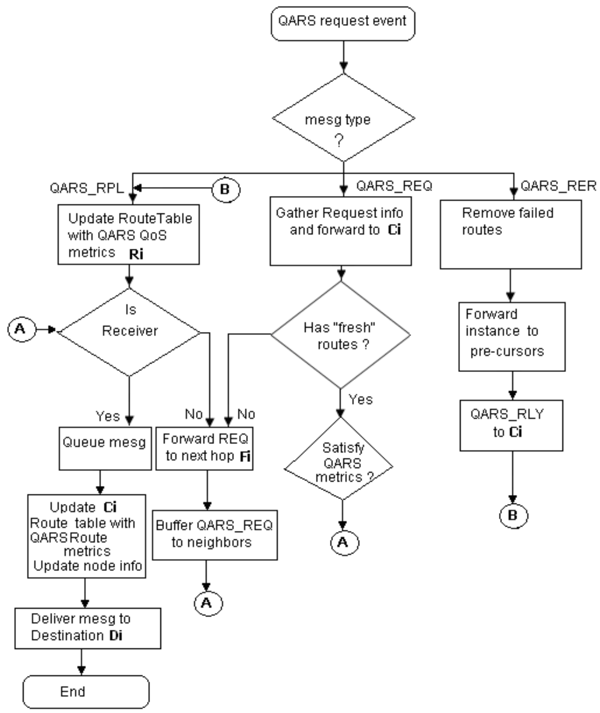

Figure 3. Flow Chart of IGLAR

The phenomena of identifying the optimal route IGLAR_OPT is highly dependent on 'Hopk' - the number of hops selected between source 'S' and destination 'D', μ and ζ, the vehicle, service priority respectively. The bandwidth on demand can be provided to nodes and services with high priority with help of VANET nodes which is discussed in Step 15 to 18. Step 19 requests the optimal route for session establishment, for which reply is received and session is established. If the wait time interval τ is maximum, then time out is declared and session is reset as shown in Steps 22 to 25. The best optimal route is stored in cross-road node Ci or Ri (Step27), while request is forwarded for a session route update in Step 28. The flow chart of IGLAR message handling routines is discussed as shown in Fig 3.

This process simplifies the execution flow of IGLAR_OPT algorithm for IGLAR_REQ, IGLAR_RPL messages with error handling support in IGLAR_RER. IGLAR_RER is generated when a node or link had failed during transmission, the packets transmitted to the failed node has to be informed to neighbor forwarding node Ci. The forwarding node Ci at cross roads re-transmits or broadcasts the data to avoid intermittent delay at receiver end.

4. Simulation Test Bed

The simulated behavior of vehicles can be conceived with specific QoS parameters such as "desired velocity", "direction of vehicle", "change of lane information", which were used to model different types of road users. VANET nodes were classified into type Truck which can travel at maximum speed of 22.2m/s (approx. 60 to 80km/h) and vehicle of type Car which can travel at an average speed of 33.0m/s (approx. 80 to 120kms/hr). The simulations were performed at an average density of 4.2 vehicles per kilometer in a lane, representing less density or 20 vehicles per km in a lane, representing peak hour traffic. The simulation test bed is scripted in ns2 for three VANET protocol models namely GPSR, DYMO and IGLAR. The high way road of Surat city is chosen as test scenario map which is supported in VanetMobisim[14]. (Fig-5).

To model the test bed scenario, two different case studies were considered. The performance of IGLAR protocol is evaluated in high contention environments:

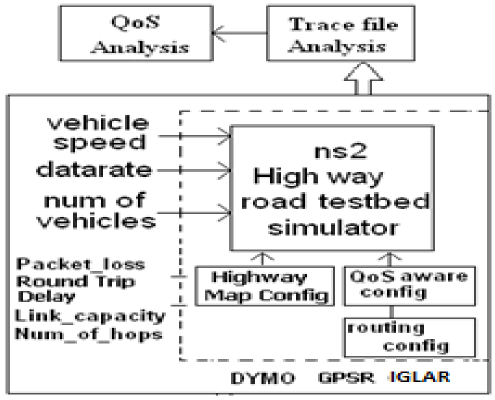

Figure 4(a) Simulation Test Bed Setup

(1) a high way urban road environment with major obstacles which message using periodic "hello" and the standard 802.11 MAC protocol. VanetMobiSim supports the road map against real vehicular traces along the road.

(2) an urban environment without obstacles, using IGLAR's proposed forwarding optimization routing scheme, across the roads.

Network Simulator	ns-3.1
Mobility Models	VanetMobiSim
DYMO Implementation	DYMO-AODV
Hello interval	3s
AQVA Implementation	AQVA-OLSR [10]
Hello Interval	0.5s
REQ/RES interval	2ms
Simulation time	1000s
Simulation Area	1000m x 1000m grid
Number of Nodes	5,10,20,40,50
Tx Range	100m
Speed	Dynamic
Density	# of nodes*(π*range^2)/(Xaxis*Yaxis)
Data Type	CBR
Data Packet Size	512 bytes
MAC Protocol	IEEE 802.11 DCF
MAC Rate	2 Mbits/s
Confidence Interval	95%

Figure 4(b) Test Bed parameters in NS-3

A vehicular traffic generator "car-following model"[16] proposed by Gipps, had been suggested. This model enables vehicles "on mobility" such that it can move at maximum safest speed to minimum speed as well avoids collisions. But the disadvantage of this model is that it does not support real time scenario road maps, hence as another alternate VanetMobisim[14] is used for traffic generation. The test bed is executed using different scenario as shown in Table-1, the data rate is scheduled Fig 4(b) with varying vehicular speed used on highway roads. The parameters defined are as per standard adopted in IEEE 802.11 MAC support for number of nodes and transmission / Receiver range.

Table 1. Highway road simulation parameters

Scenarios	Data Rate [Mbits/s]	Speed Mobility [m/s]	Nodes Density	Road Length [m]	Node Support	Tx /Rx Range
Vehicle to vehicle	11Mbps	$S_{min} = 20$ $s_{max}=50$	10 – 15	10	30	100
Road Segment	54Mbps	$S_{min} = 20$ $s_{max}=50$	40 - 60	20 to 50	40 to 60	100
Lane Segment	120Mbps	$S_{min} = 20$ $s_{max}=50$	35 -45	30 to 60	60 to 80	400
Cross Road	200Mpbs	$S_{min} = 60$ $s_{max}=100$	50 - 80	10 to 100	80 to 120	200
Vehicle to RSU	100 Mbps	$S_{min} = 60$ $s_{max}=100$	60 - 100	20 to 100	50 to 70	100

Figure 5 Surat city Digital Road map– Test bed

5. Performance Analysis

Performance was measured at varying VANET node densities such as of 4, 7, 15, and 25 vehicles per kilometer and lane, corresponding to chosen traffic densities along a high way road map as shown in Fig-7. Vehicles are categorized into ‘High Priority’, ‘Ambulance’, and ‘Normal Priority’. The fig also shows Cross-road nodes which carry shareable bandwidth, which all nodes can share for QoS on demand services. Ambulances and High priority nodes were given higher IGLAR QoS support compared to other nodes, which utilized the Cross-Road node more for utilizing its share of bandwidth. The Normal Priority nodes followed behind and used intermediate forward nodes for transmission.

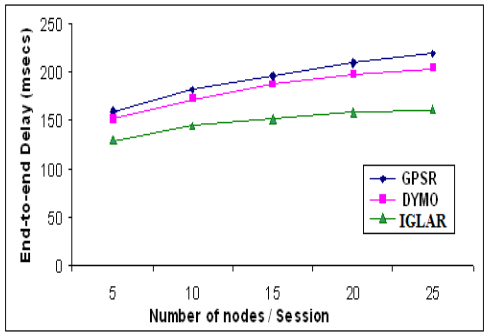

Figure 6 End-to-end delay measured using High Priority VANET nodes

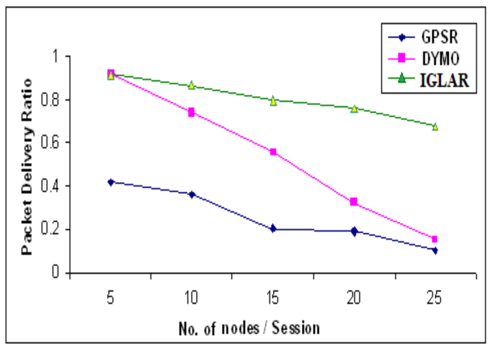

Figure 7 Packet Delivery Ratio at receiver nodes over VANET nodes

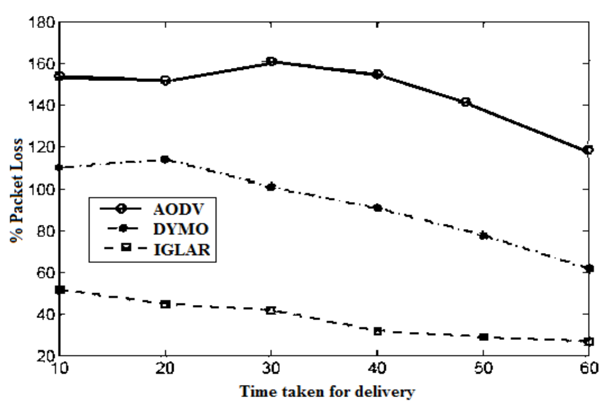

Figure 8 Packet loss achieved at cross nodes

IGLAR's performance was better in controlling packet loss, an increase in throughput of around 15% compared to AODV and 30% compared to GPSR using the IEEE 802.11 standard. In terms of average delay, IGLAR performed best, with delays as much as 85% lower than DYMO and GPSR. The proposed forwarding optimization provided noticeable improvements in the high contention scenario. The scenario with obstacles yielded better performance, even without using the optimization. This was the result of lower contention in the network as well as the fact that IGLAR protocols forward data along the roads, and across the roads. Fig6 shows the performance of IGLAR in comparison with the surveyed protocol. It was noticed that delay for GPSR, DYMO was on average 12% high compared to IGLAR, as the number of nodes was slowly increased to 25, the performance of IGLAR differs to a greater extent with difference of around 90ms. On average IGLAR performs end-to-end delay of 125ms, while

DYMO shows 192ms and GPSR 210ms.

Fig-7 shows the performance of IGLAR as PDR (packet delivery ratio), which explains the throughput or packet loss ratio (in %). From fig, it can be understood that performance of IGLAR and DYMO was high initially (average 100%), while GPSR delivered only 40% of transmitted data. As number of nodes was increased, it was found that IGLAR shows loss of 20% of its data but DYMO and GPSR loses around 90% of its data. The performance of IGLAR is comparatively better than DYMO and GPSR. Fig-8 demonstrates the percentage of packet loss achieved at intermediate cross roads where the performance of IGLAR was better than compared to DYMO and AODV.

Conclusion And Future Work

This research work IGLAR focuses on providing QoS on demand for vehicles which works on bandwidth hungry applications. Major contribution from this research work focuses towards providing QoS for 'on demand services', for vehicle on dynamic mobility. Efforts on controlling vehicles with variable speed, lane change, vehicles at cross-roads are well established through simulated results. So far major works on priority for vehicles and services are not discussed; hence such works are not taken for survey as part of literature study.

Future work can be focus towards,

[a] Improving the reliability and creditability which is the major challenge in protocol design in VANET.

[b] A real time study on VANETs and experimental approach should be adopted to improve quality.

[c] Aspects on Driver behavior (drowsiness, drunken driving, rashness) should be considered for designing of delay bounded routing protocols since carry and forward is the mainly approach to deliver packets.

IGLAR can be improved in future with need to support on real time streaming services.

Referrences

[1] Connectivity-Aware Routing (CAR) in Vehicular AdHoc Networks by Valery Naumov and Thomas Gross

[2] R. Tatchikou, S. Biswas, F. Dion, Cooperative vehicle collision avoidance using inter-vehicle packet forwarding, in: IEEE Global Telecommunications Conference (IEEE GLOBECOM 2005), St. Louis, MO, USA, November 28–December 2, 2005, pp. 2762–2766.

[3] A. Buchenscheit, F. Schaub, F. Kargl, M. Weber, A VANET-based emergency vehicle warning system, in: First IEEE Vehicular Networking Conference (IEEE VNC 2009), Tokyo, Japan, October 28–30, 2009, pp. 1–8.

[4] M. Fiore, J.M. Barcelo-Ordinas, Cooperative download in urban vehicular networks, in: Sixth IEEE International Conference on Mobile Ad-hoc and Sensor Systems (IEEE MASS 2009), October 12–15, 2009, University of Macau, Macau SAR, PRC, 2009, pp. 20–29.

[5] L. Zhou, Y. Zhang, K. Song, W. Jing, A.V. Vasilakos, Distributed media services in P2P-based vehicular networks, IEEE Transactions on Vehicular Technology 60(2) (2011) 692–703.

[6] L. Franck, F. Gil-Castineira, Using delay tolerant networks for Car2Car communications, in: IEEE International Symposium on Industrial Electronics 2007 (ISIE 2007), Vigo, Spain, June 4–7, 2007, pp. 2573–2578.

[7] Raya, M., & Hubaux, J. (2005). The security of vehicular ad hoc networks. In Proceedings of the 3rd ACM workshop on security of ad hoc and sensor networks (SASN 2005) (pp. 1–11), Alexandria,VA.

[8] Perkins, E. Belding-Royer, and S. Das, "Ad Hoc OnDemand Distance Vector (AODV) Routing", RFC 3561, Network Working Group, 2003.

[9] B. Karp and H.T. Kung, "GPSR: Greedy perimeter stateless routing for wireless networks", in Proceedings of the ACM/IEEE International Conference on Mobile Computing and Networking (MobiCom), 2000.

[10] F. Ros, P.M. Ruiz, and I. Stojmenovic, "Reliable and efficient broadcasting in vehicular ad hoc networks", IEEE the 69th Vehicular Technology Conference (VTC'09), Spain, April, 2009.

[11] C. Lochert, M. Mauve, H. Fubler, and H. Hartenstein, "Geographic routing in city scenarios", ACM SIGMOBILE Mobile Computing and Communications Review (MC2R) [C], vol.9, no.1, pp. 69-72, Jan 2005.

[12] The DYMO Routing Protocol in VANET Scenarios by Christoph Sommer , Falko Dressler

[13] DSRC Standardisation and Conformance Testing of DSRC / EFC Equipment

[14] VanetMobiSim: Generating Realistic Mobility Patterns for VANETs by J. Haerri, F. Filali, C. Bonnet

[15] http://www.nsnam.org

[16] A behavioural car-following model for computer simulation by P.G. Gipps