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A Consistent Routing Protocol Based On Graph Theory For Efficient Vehicle To Vehicle Communication

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***Abstract*—** Vehicular Ad-hoc Networks (VANETs) are made exclusive for vehicular communications in which each node makes a bidirectional connectivity with other nodes. VANET has attracted more researchers and has unlocked a track to cultivate few applications like propagation of travel alerts, traffic status, and user defined applications. Each node in VANET has some unique features like dynamic network structure, high mobility, low processing speed and low memory. These features make VANET unique and different from other wireless networks. These features need a special attention, while designing a routing protocol to VANETs. This paper proposes a novel consistent routing protocol called CRP for inter vehicular communications to achieve a consistent and reliable route between the source and destination. Based on link reliability value and graph traversals, a source node predicts a reliable path among the neighboring nodes. The proposed algorithm is designed to work in a stressful urban environment and significantly outperforms than the other existing algorithms.

***Keywords*—**Consistent, graph theory, protocol, reliable, vehicle ad hoc networks (VANETs), wireless, urban

I. INTRODUCTION

VANET is a unique and special form of ad-hoc network. It is different from Mobile Ad-hoc Network (MANET) [1] because the communication link between the nodes breaks frequently. The parameters that affect the reliability of links are network density, velocity of a vehicle, congestion in a wireless channel etc. Vehicular communication enables a way to communicate a vehicle from another. Each node in VANET can generate, forward and receive messages without a proper structure. The forwarded messages mostly exchange messages like real-time traffic update, weather information, emergency messages etc. The main objective of VANET is to enhance the safety of driver and passengers on road and ultimately decreases the number of roadway accidents. As the number of vehicles increase day by day the rate of accidents, injuries and death also increases. Typical VANET do not have an ability to save the human life because of unreliable communication links between the nodes. Therefore it is important to develop a consistent routing protocol between the vehicles even though the reliability of the link is unpredictable.

The graph theory can be modeled to showcase the behavior of VANET, where the vehicles and their unreliable communication links can be pictured as vertices and edges respectively. Evolving graph [2] [3], an advanced concept in graph theory is proposed recently to model a dynamic network and their behavior. Unfortunately, an evolving graph is fit perfect with MANETs and other similar networks, where delay is bearable or change in network behavior is predictable over time. In order to address the topological properties of VANETs, a modified evolving graph has to be considered.

The objective of this manuscript is to design a consistent routing protocol (CRP) for VANETs. It is really important to address the issue of unreliable links caused by vehicles in different speeds. The contributions are listed below.

(i) A modified evolving graph is modelled to display the unique properties of VANETs.

(ii) A link reliability value is calculated based on mathematical analysis of vehicular movements, their velocities and channel availability.

(iii) A novel and unique protocol called Consistent Routing Protocol (CRP) is developed using an evolving graph. New routes are discovered without the help of periodic beacons and it significantly reduces the overhead of a wireless channel.

We assume that the velocity of the vehicles remain constant. It is also assumed that a source node updates the value of link reliability value among the different links in a frequent time interval. Varying velocities and irregular traffic flows on a road remains uncovered.

The rest of the manuscript is organized as follows. Section 2 focuses on a detailed literature study. The complete dynamic behavior of VANETs and mathematical calculation of link reliability value is presented in Section 3. VANET based reliable graph model is explained in Section 4. The proposed consistent routing protocol is explained in Section 5. Section 6 covers the results and discussion. Section 7 gives the conclusion and possible future studies in this topic.

II. LITERATURE SURVEY

The literature survey covers the existing ideas and concepts related to vehicular reliability, use of graph theory especially evolving graphs and type of messages that can be passed among the nodes. Thus we divide the section into three sub-sections.

2.1. Vehicular reliability

Taleb et al. [4] proposed a predictable link based reliability model for clustered VANETs. The vehicles that have similar velocities are added in a single cluster. If a vehicle changes its velocity, it will be temporarily added to another cluster and the proposed scheme tries to find a stable route among the vehicles in the same cluster. Feng et al. [5] proposed a trajectory based routing protocol called velocity-aided routing protocol. It forwards the packets to a forwarding zone where the actual destination is located by calculating future trajectory. Maximum predicted route lifetime is focused in prediction based routing, suggested by Namboodiri et al. [6]. Each route is divided into a number of sub-routes and the lifetime of each route is calculated separately by formulating a route which has a maximum lifetime.

Hao Jing et al. [7] proposed reliable and efficient alarm message routing (REAR) to broadcast alarm messages. The contention in the receiving node is calculated in REAR to broadcast alarm messages efficiently. A reliable routing protocol based on mobility prediction (RB-MP) is proposed by Peiyuan et al [8]. Rebroadcast nodes are selected in this scheme based on prediction holding time. VeMAC: A TDMA based MAC protocol [9] is suggested by Omar et al. By introducing implicit acknowledgements VeMAC supports multi-hop communication between the nodes. Disjoint sets on time slots are introduced to the vehicles which travel in different directions and which significantly reduces the number of control messages in VeMAC.

2.2. Evolving graphs

Some recent works are available in evolving graphs to depict the properties of MANETs. Due to high mobility in vehicular nodes, an evolving graph cannot be applied directly to VANETs. At first, Monteiro et al. [2] uses an evolving graph to visualize MANETs with regular connectivity patterns. He proved that an evolving graph is well suited for wireless networks with connectivity aware patterns. Pallis et al. [10] explained the complete characteristics and statistical features of a typical VANET.

2.3. Messages in VANETs

Based on the various applications of VANET, the inter-vehicle communication (IVC) protocols are classified as (i) information messages (ii) safety messages (iii) individual drive control message (iv) group drive control message. The general description about the various messages and some of the applications and examples are shown in Table 1.

Type 1 and Type 2 messages provide some general information services and are mostly aimed at vehicles on the roadways. The vehicle itself becomes a source for Type 1 and Type 2 messages and the requested information may be propagated comprehensively. Type 1 messages are not concerned about vehicular safety. Some examples are mobile Internet and RSS feeds. Type 2 messages are related to safety-related services, such as propagation of emergency messages, collision alerts, weather and road conditions, and obstacle awareness. Type 2 applications deal with very sensitive data, hence smaller delay and low propagation losses must be ensured. The messages propagated in Type 1 and Type 2 applications do not automatically control the vehicles.

Type 3 and Type 4 messages automatically control the vehicles on a real-time basis so these messages are naturally sensitive. The messages aim to provide guidelines for the motion and actuator unit (e.g., throttle and brakes) of the vehicles. Type 3 applications focus on an individual vehicle and Type 4 applications deal with a group of vehicles, where the vehicles travel in a dense environment. Type 3 and Type 4 messages are communicated in relatively short timescales, such as milliseconds. Type 3 application moves the unrelated vehicles out from the planned vehicle’s way by using individual drive planning and regulation methods. Best Examples are runway incursion avoidance for flights and adaptive automobile cruise control. Apart from Type 3 applications, Type 4 applications share their drive control and regulation methods amongst vehicles that may also couple their drive plan to one another.

Some notifiable examples are optimal path planning amongst air routed tri-copters, group of vehicles or vehicle platoons, and flying plan of various aircrafts. Shared planning and control may be executed jointly amongst vehicles or performed by a head and communicated to other vehicles. In a highly coupled group, the entire motion of the group may depend on the current inputs from the head and one another.

If the entire group is not highly coupled and head-based directives are not desirable, the vehicles may create a "virtual head" reference through distributed consensus rules.

The application classes can be ordered into a classification based on how the IVCs are used, as shown in Figure 1. The root of the tree hierarchy represents all IVC application classes. Travelling towards right from left, all the IVC applications are first divided by whether they involve transmission of drive control messages between the vehicles; Type 3 and Type 4 do, whereas Type 1 and Type 2 do not. Going further towards right, Type 2 services are detached from Type 1 because Type 2 applications are naturally sensitive messages and delay in the service is unbearable. Drive control messages are subdivided by whether they involve individual planning; Type 3 does, whereas Type 4 does not. Type 3 control messages are used to control a single vehicle. Type 4 group drive control applications are divided according to the control architecture they use to normalize their motion.

Figure 1. Division of IVC services and applications.

III. Dynamic Behavior of VANETs and Link Reliability Value Calculation

To understand more about the behavior of VANET, reliable communication link between two independent vehicles can help us. The reliability among the nodes is highly disturbed due to vehicular mobility and traffic density on a road. Link reliability value is a useful measure to exhibit the reliability of the wireless links.

3.1. Macroscopic view of vehicular traffic flow models

Macroscopic view describes the traffic flow on a road as a physical flow on a continuous basis. It takes three different key terms, such as traffic density, traffic flow and vehicle's average velocity. They are denoted as $t_d(x,t), t_f\left(x,t\right)$ and $v(x,t)$

Here x denotes a function space and t denotes a time corresponds to partial differential equation. Based on the average values [11], the following relations are identified for a macroscopic view.

$$Distance\ between\ two\ vehicles$$
$$= \left(\frac{1000}{Traffic\ Density}\right) - Average(Vehicle\ Length) \quad (1)$$

$$Average\ time - gap\ between\ two\ vehicles$$
$$= \left[\frac{Distance\ between\ two\ vehicles}{Average\ velocity\ of\ vehicles\ on\ the\ road}\right]$$
$$\left[\frac{1}{Average\ velocity\ of\ vehicles\ on\ the\ road}\right]$$
$$\times\left(\frac{1000}{Traffic\ Density}\right) - Average(Vehicle\ Length) \quad (2)$$

$$Average\ distance\ between\ two\ vehicles$$
$$= \left[\frac{1}{Average\ time - gap\ between\ two\ vehicles}\right]$$
$$= Average\ time - gap\ between\ two\ vehicles$$
$$\times\left[\frac{1}{\frac{1000}{Traffic\ Density} - Average(Vehicle\ Length)}\right] \quad (3)$$

3.2. Link reliability value calculation

Link reliability value $(l_r(e))$ is a probability value i.e, $0 \le l_r(e) \le 1$ is determined from direct communication between two vehicles a and b for a specified time period t. Let us consider the time interval is t_i , and the link exist between a and b is $\delta_{(a \to b)}$ then the link reliability value $(l_r(e))$ can be measured as $(l_r(e)) = P\left\{Link\ continues\ from t\ to\ t + t_i\right\}$

3.3. Identifying the most reliable route

In a dense environment, more than one possible route may exist from source to destination. It is also true that more than one link exists between the source and the destination. For simplicity, let us assume the available links are expressed as $l_1, l_2, l_3 ... l_n$ and l_1 =(source's', hop_1), l_2 = (hop1,hop2)… l_n =(hop_n ,destination 'd').

The reliable route RR can be expressed as,
$$RR = \prod_{n-2}^{n-1} (l_r(e))_i + (l_r(e))_{source's' \to h_1} + (l_r(e))_{h_n \to destination'd'}$$

IV. VANET based Reliable Graph Model

4.1. Motivation

The evolving graph model cannot be alone useful to VANETs. As it does not consider the unfailing nature of the communication links among nodes, we extend the evolving graph model as VANET based Reliable Graph model, called VbRG, to accomplish reliability by estimating the changing configurations of vehicular traffic. These configurations are estimated based on the road network and the statistics of vehicles. VbRG considers reliability of all the communication links among vehicles. We present the nature of the evolving graph model and the extended version to propose the VbRG model.

4.2. Nature of the evolving graph model

The evolving graph theory is a strict generalisation for active networks and a method of time evolution in a formal way. It is an indexed order of γ subgraphs of a particular graph, and all the subgraphs are estimated for reliable link communications based on a time domain T where $T = (t_{i-1}, t_i)$. Figure2 represents the graph connectivity in VANETs. It has nine vehicles from V1 to V9. There can be more than one route from the source to the destination and choosing the most optimal route is a big task.

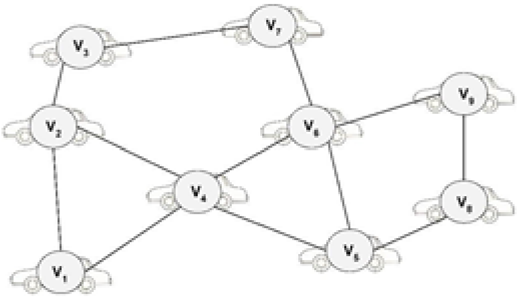

Figure 2. Graph connectivity in VANETs.

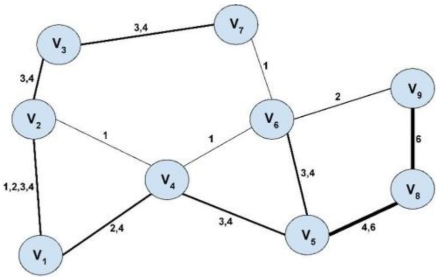

Figure 3. Evolving graph model.

Figure 3 represents the evolving graph model with time intervals on the edges. We can note that {V1, V4 , V6 } is an invalid journey because the edge {V4 , V6 } exists only in the past and the time intervals in the edges should be in an increasing order. Some of the valid journeys are {V1, V4 , V5 , V8 , V9 }, {V1, V2 , V3 , V7 } as shown in the figure with dark solid lines. Let G (V, E) be a given graph and the sequence of γ subgraphs be $S_G = G_{t1}, G_{t2}, G_{t3} \ldots G_{tn}$ i.e. $G_{t1} = (V_1, E_1)$, …. $G_{t\gamma} = (V_\gamma, E_\gamma)$ such that. $\bigcup_{i=1}^{\gamma} G_i = G$ The system $E_G = (S, S_G)$ is called an evolving graph. The set of vertices of is $\{V_G \cup V_i\}$ and the set of edges of S_G is $\{E_G \cup E_i\}$.When E_G is traversed on the edges it is called as timed evolving graphs (TEGs). Let R be a route in the E_G , where R= (e_1, e_2,…e_k) such that E_G in G. Let $R_\lambda = \lambda_1, \lambda_2 \ldots \lambda_k$ where $\lambda_y \in T$ when a route R is traversed using an edge it should be within a discrete time interval. We define a journey

J = (J = R, Rt) which should correspond to G, R and T . It should be noted that journeys cannot go back to the past. The current E_G model works based on three metrics: the earliest, fastest and shortest journey. They are based on the minimum number of hops, minimum delay and minimum time interval.

4.3. VbRG (VANET based Reliable Graph)

We propose the VbRG model that concentrates on the reliability of communication links i.e., the edges among vehicles. Figure 4.1 and 4.2 represent an instance on a roadway at two time intervals: t_i = 0 second and t_i = 10 seconds. Nodes V_1 to V_9 represent the vehicles and a 2 -tuple representation is made on each edge, say $(t_i, t_r(e))$ where ti represents the time at i th second and $t_r(e_y)$ represents the reliability value between the nodes. When $t_r(e) = 0$, there is no communication between the two vehicles as its reliability value is equal to 0. Since it concentrates more on reliability, the link is more continuous between the vehicles when compared to the existing mechanisms. Thus, when $t_r(e) > 0$, the journey is valid and we do not need to care about the presence of communication links and its time interval.

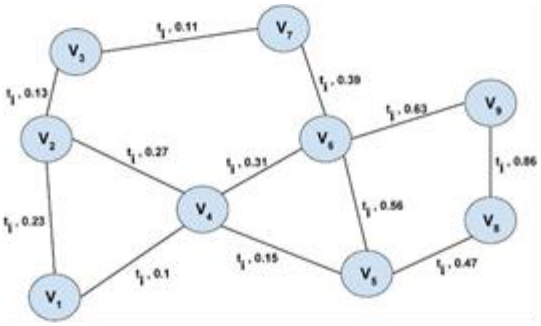

Figure 4.1. Proposed VbRG model at t_i=0 second

Figure 4.1 represents the proposed VbRG model with vehicles on a roadway at ti=0 second. The reliability value $t_r(e)$ between V1 and V_2 is 0.23. Let VJ (e) represents a function to check whether it is a valid journey or not corresponding to an edge. If the reliability value of a link l_r(e) lies between 0 and 1, it is valid and if it is equal to 0, it is considered as an invalid journey.

$$VJ(e) = \begin{cases} True\, if\ 0 < l_r(e) \leq 1 \\ False\, if\ l_r(e) = 0 \end{cases}$$

Consider Figure 4.2 which changes over time t_i=10 seconds, where the reliability values are changed due to the introduction of VbRG model.

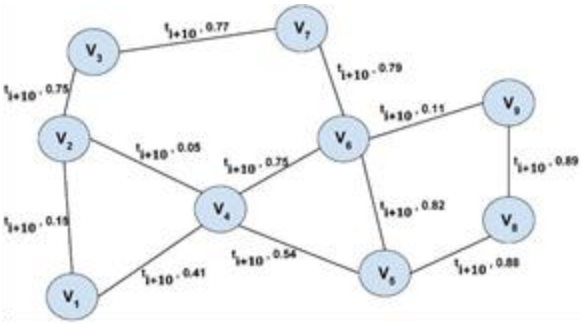

Figure 4.2. Proposed VbRG model at t_i=10 seconds.

Though are many routes to reach the destination vehicle V9 from the source vehicle V1, selecting the ideal route is a key issue. So it is necessary to analyze the routing mechanism for analysing the reliability of journey in VANETs. A journey should be most reliable from the source to the destination. The metric for identifying the most reliable journey is J_{MR} in which there be k edges between the nodes a and b in G and $t_r(e_y)$ represents the reliability value of edge e_y at time t_i where C=(R, R_t) and y = (1, 2, 3...k). It is defined as follows:

$$R(J_{MR}(a,b)) = \prod_{y}^{k} t_r(e_y)\ where\ e_y \in R(J_{MR}(a,b)) \quad (7)$$

From equation (7), it is noted that the journey reliability value is equal to the product of the reliability value of all the links that are formed, where

$$0 \leq R(J_{MR}(a,b)) \leq 1 \quad (8)$$

If there are p possible journeys from a to b, the most reliable journey will be a set of all those possible journeys from (J1,J 2 ...J p). i.e., J $_{MR}$ = (J1, J 2 ...J p). The selection of the most reliable journey will be based on

$$\max_{J \in J_{MR}(a,b)} R(J) \quad (9)$$

V. The Proposed Consistent Routing Protocol (CRP)

In the previous section we proposed VbRG model for describing the VANET communication graph. We design a new routing protocol for reliable packet delivery among the vehicles. A strict routing constraint has to be followed when we search a route from the source to the destination. As there should not be link failure, we adopt a new route discovery procedure so that the journey becomes valid and reliable. A new routing algorithm is used to find the most reliable journey and using the algorithm we design the route discovery procedure for our proposed RG- AODV Reliable Graph – Ad hoc On Demand Distance Vector routing protocol.

5.1. Consistent algorithm

A mobility model is needed for tracking the exact location of vehicles at time t. For convenience, we assume that the vehicles travel in the same direction at a constant velocity V0 Under this assumption each vehicle l is defined with two parameters and they are

(i) Current velocity V_l (t) = V_0 .
(ii) Current Cartesian Position at t : a_l(t) and b_l(t).

The direction of travel δ1 (t) = δ_0. Using the City Section Mobility model (CSM)

$$\Delta a_{i,j} = V_0 * \Delta t * \cos \delta_0$$
$$\Delta b_{i,j} = V_0 * \Delta t * \sin \delta_0 \quad (10)$$

where $\Delta a_{i,j}$ and $\Delta b_{i,j}$ are the travelling distances during Δt .

5.2. RG-Dijkstra

We cannot directly apply the Dijsktra's algorithm. So we propose the RG-Dijkstra's algorithm to find the most reliable journey MRJ. It is equal to find the most reliable route. The proposed algorithm has a database DB which has a collection of reliable data about all the vehicles and it's associated most reliable value. It is collectively called as reliable data (RD) which is initialized as 1 for the source and φ for the other vehicles, say RD(src) = 1 and RD(dest) = φ.

The journey starts from the source vehicle and the other vehicles are unvisited at that current time instance. The reliability value is calculated from the source and the vehicle which has the most reliability value is chosen and is marked as visited. Thus, the process continues until it reaches the destination. The pseudo code of the RG-Dijkstra's algorithm is as follows:

```
Input. VbRG and source vehicle src.

Output. RD that has the collection of reliable data about
        all the routes from the src.

Variables. A set U of all unvisited vehicles.

Step 1. Set reliability RD (src) = 1 and RD (dest) = φ for all the other vehicles.

Step 2. Initialize the DB by introducing src.

Step 3. While DB is not empty,

Step 3.1.  a ← vehicle with the highest value in U.

Step 3.2. Mark a as visited.

Step 3.3. For each neighbour b of a do

Step 3.4. if VJ (e) is true

Step 3.4.1. Set  RD(b) ← $t_r$ (e) * RD(a)

Step 3.4.2. Insert n if not visited in DB.

Step 3.5. Close a.

Step 3.6: Update DB.
```

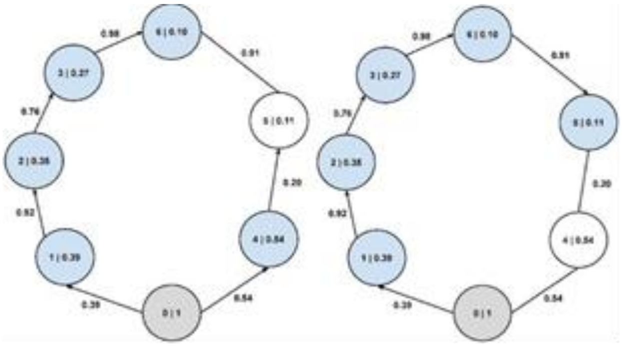

Figure 5.1. Example of RG – Dijkstra on VbRG at t_i = 0 second.

Figure 5.1 shows an example of the Dijkstra algorithm at two time instances: t = 0 second in which the source vehicle src is node 0 and the destination vehicle dest is node 5. The reliability value of the link is represented along each edge. In Figure 5.1 (a) it starts from src 0 and checks for the most reliable value and chooses the route with the most reliable value 0.54 and reaches vehicle 4. As it moves on, it reaches the destination vehicle 5 which has a low reliability value of 0.20 as shown in Figure 5.1 (b).Though it has reached the destination, VbRG has to check for all possible routes from the src. So it takes another route as observed in Figure 5.1 (c). It does not stop with vehicle 6 as the destination is vehicle 5. After it reaches vehicle 5 it finds that it is the most reliable route for the journey as it has 0.91 as the most reliable value when compared with the other route with the value 0.20. Thus from 5.1.(d), the final reliable graph is {0 → 1 → 2 → 3 → 6 → 5} and the computation is as follows:

Reliability value of src 0 is 1.

Reliability value of node 1 = Reliability value of node 0 * Link Reliability value of the edge between nodes 0 and 1.

= 1 * 0.39 = 0.39

Reliability value of node 2 = Reliability value of node 1 * Link Reliability value of the edge between nodes 1 and 2.

= 0.39 * 0.92 = 0.35

Reliability value of node 3 = Reliability value of node 2 * Link Reliability value of the edge between nodes 2 and 3.

= 0.35* 0.76 = 0.27

Reliability value of node 4 = Reliability value of node 0 * Link Reliability value of the edge between nodes 0 and 4.

= 1 * 0.54= 0.54

Reliability value of node 5 = Reliability value of node 4 * Link Reliability value of the edge between nodes 4 and 5.

= 0.54 * 0.20 = 0.11

Reliability value of node 6 = Reliability value of node 5 * Link Reliability

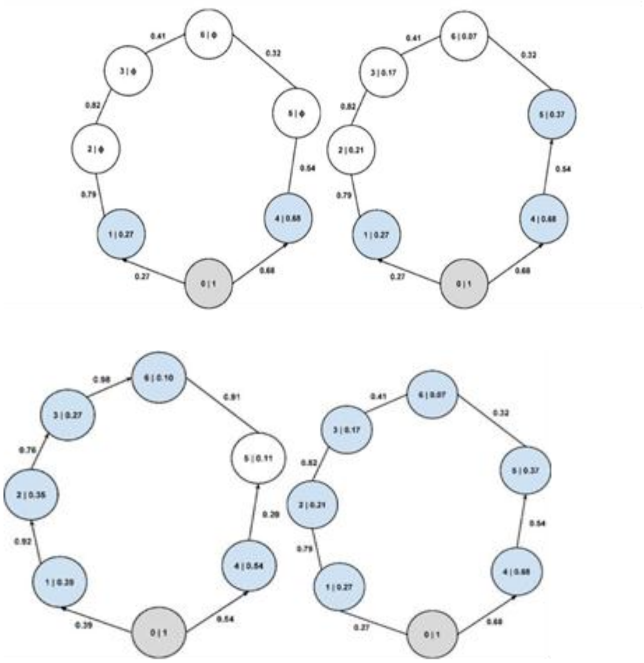

Figure 5.2. Example of RG – Dijkstra on VbRG at t_i=10 seconds

5.3. Identifying the route in RG-AODV.

The pseudo code of RG-AODV for identifying the routes is as follows:

```
Input. A VbRG, a source vehicle src = $a$ and destination vehicle $dest$ = $b$.
Output. Identification of $J_{MR}$ from $src$ to $dest$.

Step 1. Retrieve the status of VbRG from the mobility algorithm.

Step 2. Compute the reliability values for all the links.

Step 3. $J_{MR} \leftarrow$ RG- Dijkstra (VbRG, a).

Step 4. while $DB$ is not empty

    Step 4.1. a $\leftarrow$ first node in $J_{MR}$ .

    Step 4.2. Insert $m$ in the $DB$.

    Step 4.3. Send $R_{req}$ from m along $J_{MR}$ .

    Step 4.4. while $R_{rep}$ is not received, wait.

    Step 4.5. Send data until reply is received.

    Step 4.6. While $R_{rep}$ is received, mark b as destination.
```

At time t, the source vehicle has data to send to another vehicle b calculating the reliability values per link. The RG-Dijkstra finds the most reliable journey from the source to the destination vehicle. As the source alone has the current status of VbRG, it will create a request message for routing in order to identify the most reliable route.

So broadcasting of messages and its overheads are avoided. A routing reply message Rrep is expected from the destination back to the source. Intermittent nodes are not allowed to send reply even if the route can be taken as valid. It should be noted that due to mobility of vehicles, the reliability values of the links are also subject to change due to its dynamic nature. So, when Rreq is received at the destination vehicle, it should immediately send an Rrep back to the source so that it can start transmitting data.

This route identification mechanism works only on-demand i.e., whenever a valid route is requested, a reply is obtained. In another case, it calculates the valid route from the source to the destination based on the information obtained from VbRG, even before a request is sent. It does not use beacon messages in order to save the resources. Beacon messages are used to check whether any adjacent node is active with a valid link. Suppose that a link breaks when $t_r\ (e_{a.})$, falls below 0, a new route is discovered when a route error (R_{err}) message is obtained in such case.

VI. Performance Analysis of Consistent Routing Protocol

The main goal of this performance analysis is to check the use of CRP in a high dynamic scenario. In order to show the results, we designed a package in NS-2 [12]. Each individual runs are recorded and an average of five independent runs are shown finally. The existing algorithms which we prefer for a fair comparison are AODV (Ad-hoc On Demand Vector routing protocol) [13] and PBR (Policy Based Routing protocol) [14].When a hop-node receives a data packet from other hop-nodes it normally decides where to forward it based on the destination address given in the packets. However in PBR, the hop-nodes need to forward the packets based on the formulated networking policies. Usually policies are governed by an administrator with super user privileges.

We allowed 30 vehicles totally on a single road which has a maximum length of 5 kilometres. The simulation begins when a vehicle starts from one end and stops when it reaches the other end. Each node in a vehicle can transfer data ranges from 32 kbps to 512 kbps. The memory size of each data is 2000 bytes. Vehicles are allowed to travel in three different lanes namely L1, L2 and L3. Each lane is defined for different velocities. They are 30, 45 and 60 km/ h respectively.

6.1. Performance metrics

We considered four different parameters to evaluate the performance of CRP. It is shown below.

1. **Packet delivery ratio**. It is the ratio between the total numbers of packets successfully received at the receiver end over the total number of packets generated at the source node. It is an important analysis because the packet delivery ratio decides the overhead of a network channel. An application layer is involved in this work.

2. **Average of Link failures**. Even though reliable links are persistent during routing process, there is a potential for link failures. High mobility of the vehicle influences more in link failures. This analysis represents the average number of link failures during the routing process. This metric illustrates the efficiency of the proposed routing protocol in avoiding such link failures.

3. **Routing requests ratio**. It can be expressed as the ratio between the total numbers of requests transmitted in a finite time to the total number of pockets successfully received at the destination end.

4. **Latency**. It represents the time gap between the data transmitted and received. According to the literature, Type-2 messages are sensitive and delay is unbearable. The goal of CRP is consistency in delivering messages rather than quicker delivery. So Type-2 messages cannot be transported by using the proposed CRP.

6.2. Packet delivery ratio of proposed CRP

Figure 6 shows that our proposed CRP achieves higher and stable packet delivery ratio than PBR and AODV.

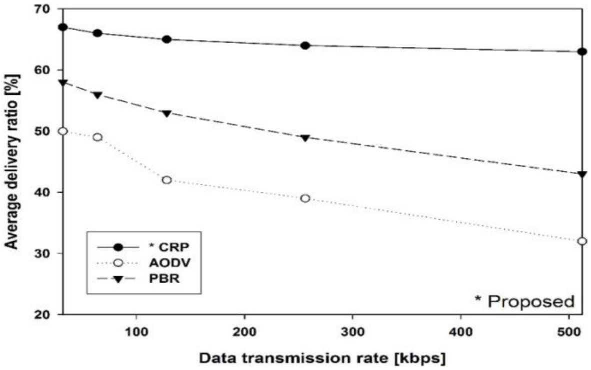

Figure 6. Packet delivery ratio analysis of CRP against PBR and AODV.

The simulation analysis show that the delivery ratio of PBR and AODV degrades when the data transmission rate increases. This is due to CRP using a consistent link which takes an advantage of evolving graph. But PBR and AODV uses periodic beacons to identify the routes. Network bandwidth is consumed more when a beacon is broadcasted. Thus CRP gives more packet delivery ratio than PBR and AODV.

6.3. Average of link failures in proposed CRP

As shown in Figure 7, the average number of link failures of the CRP protocol is minimum than that of both PBR and AODV. AODV follows a strategy called shortest-path, regardless of whether the selected route is reliable or not.

PBR performs better than AODV in terms of link failures because it predicts and decides the link lifetime and makes a new substitute route before a link breakage occurs. The strategy of PBR is proactive. But CRP uses a hybrid scenario where alternative routes are prejudged. Among the selected candidate protocols, CRP outperforms than others.

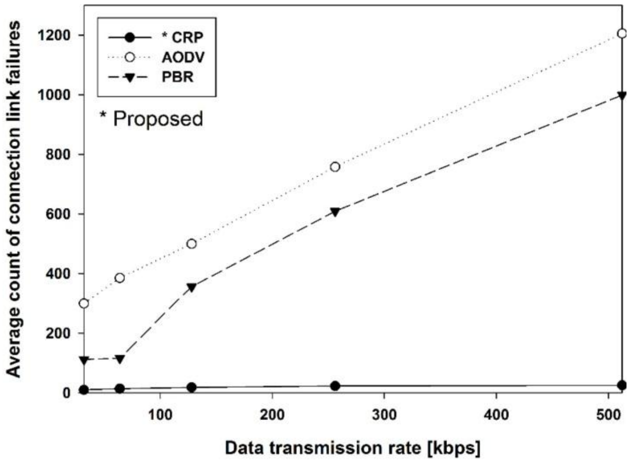

Figure 7. Average link failure analysis of CRP against PBR and AODV

6.4. Routing request ratio analysis in CRP

From the Figure 8, it is understood that the average count of routing requests in CRP is comparatively minimum than PBR and AODV protocols. CRP practically finds the most reliable route by using VbRG and directs Rreq message

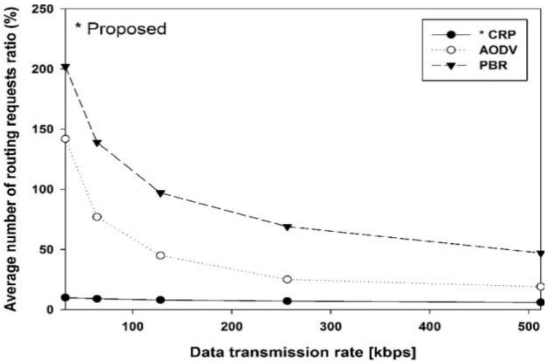

Figure 8. Average number of routing request analysis of CRP against PBR and AODV.

based on the chosen route. On the other hand, AODV and PBR keep broadcasting Rreq until they find the destination vehicle. It is noticed that PBR has the highest average routing request ratio as it has to process multiple Rreq to find a route with its maximum expected lifetime of the route to the destination**.**

6.5. Latency or delay analysis in CRP

In this simulation, CRP achieves a lower end to end delay (or) latency than AODV and PBR, as shown in Figure 9. It is also shown that the delay performance of CRP is not affected by varying the size of packets. It has a slight increase in delay when packet size increases and it is because of the fact that a bigger data packet means that more data fragments have to be delivered over the network. When one packet is considered and marked as fully delivered, it means that all its fragments of the original data are delivered completely

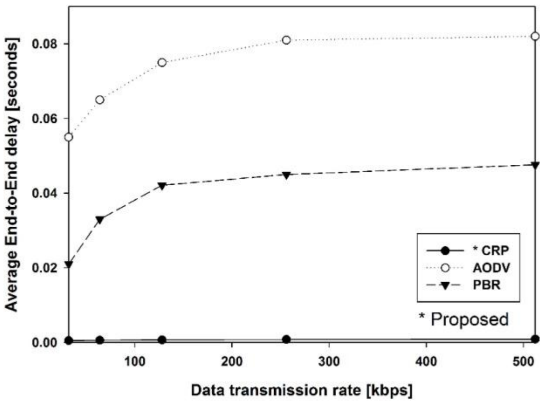

Figure 9. Average amount of latency analysis of CRP against PBR and AODV

VII. CONCLUSION AND FUTURE SCOPE

In this paper, we have proposed the VbRG model as an extension of the evolving graph theory based on the vehicular velocity on highways. The most reliable journey is found out using the RG-Dijkstra algorithm and has showed advantages of using the link reliability value to improve the performance of the existing mechanisms in VANETs. The evaluation results show that CRP outperforms well when compared with PBR and AODV. The possible future work is to use to consider different vehicular velocities and obtain congestion free consistent routes.

REFERENCES

[1] Neelesh Gupta and Roopam Gupta, "Routing protocols in Mobile Ad-hoc Networks: An overview", IEEE International Conference on Emerging Trends in Robotics and Technologies, 2010, pp**. 173-177**

[2] J. Monteiro, A. Goldman and A. Ferreira, "Performance evaluation of dynamic networks using an evolving graph combinatorial model", IEEE International Conference on Wireless and Mobile Computing, Networking and Communications, 2006, pp. **173-180.**

[3] G. Mao and B. D. O. Anderson, "Graph theoretic models and tools for the analysis of dynamic wireless multi-hop networks", IEEE Wireless Communications and Networks Conference, 2009, pp. **1-6.**

[4] T. Taleb, M. Ochi, A. Jamalipour, N. Kato and Y. Nemoto, "An efficient vehicle-heading based routing protocol for VANET networks", IEEE Wireless Communications and Networks Conference, 2006, pp. **2199-2204**.

[5] K. T. Feng, C. H. Hsu and T. E. Lu, "Velocity-assisted predictive mobility and location-aware routing protocols for mobile ad hoc networks", IEEE Transactions on Vehicular Technology 57(1) (2008), **448-464**

[6] V. Namboodiri and L. Gao, "Prediction-based routing for vehicular ad hoc networks", IEEE Transactions on Vehicular Technology 56(4) (2007), **2332-2345**

[7] Hao Jiang Hao Guo and Lijia Chen, "Reliable and efficient alarm message routing in VANET", IEEE International Conference on Distributed Computing Systems, 2008, pp. **186-191**.

[8] Peiyuan Lai, Xinhong Wang, Ning Lu and Fuqiang Liu, "A Reliable broadcast routing scheme based on mobility prediction for VANET", IEEE Intelligent Vehicles Symposium, 2009, pp. **1083-1087.**

[9] Hassan Aboubakr Omar, Weihua Zhuang and Li Li, VeMAC: "A TDMA based MAC protocol for reliable broadcast in VANETs", IEEE Transactions on Mobile Computing 12(9), **1724-1736**

[10] G. Pallis, D. Katsaros, M. D. Dikaiakos, N. Loulloudes, and L. Tassiulas, "On the structure and evolution of vehicular networks", IEEE/ACM Annual Symposium on Modeling, Analysis and Simulation of Computer and Telecommunication Systems, 2009, pp. **1-10.**

[11] M. Rudack, M. Meincke, K. Jobmann and M. Lott, "On the dynamics of ad hoc networks for inter vehicle communication (IVC)", International Conference on Wireless Networks, 2002.

[12] I. D. Chakeres and E. M. Belding-Royer, "AODV routing protocol implementation design", IEEE International Workshop on Distributed Computing Systems, 2004, pp. **698-703.**

[13] Kavin Tantipongsakul and Akharin Khunkitti, "Dynamic policy-based routing using firewall rules", IEEE European Symposium on Computer Modeling and Simulation, 2009, pp. **540-545.**

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