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REVIEW ARTICLE

A GRAPH-BASED RELIABLE ROUTING SCHEME FOR VANETS

***[1]Khan Anam and [2]Beena Ballal**

[1]VIT ME pursuing, Mumbai, India
[2]VIT Assistant professor, Mumbai, India

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ABSTRACT

Vehicular ad hoc networks (VANETs) are a special form of wireless networks made by vehicles communicating among themselves on roads which includes communications among vehicles and between vehicles and road side units. However, due to the high mobility and the frequent changes of the network topology, the communication links are highly vulnerable to disconnection in VANETs. This paper extend the well-known ad hoc on-demand distance vector (AODV) routing protocol with evolving graph theory to propose reliable routing protocol EG-RAODV. Simulation results demonstrate that EG-RAODV significantly outperforms better packet delivery ratio, lowest routing request ratio, less link failures while maintaining a reasonable routing control overhead and lowest average end to end delay.

INTRODUCTION

The number of automobiles has been increasing on the road from the past few years. Due to high density of vehicles, the potential threats and road accident is increasing. VANET is one of the influencing areas for the improvement of Intelligent Transportation System (ITS) in order to assists vehicle drivers to communicate and coordinate among themselves in order to avoid any critical situation before they actually face it, which significantly improve driver's safety and comfort. Inter-vehicle communication (IVC) is necessary to realize traffic condition monitoring, dynamic route scheduling, emergency-message dissemination and most importantly, safe driving. It is supposed that each vehicle has a wireless communication equipment to provide ad hoc network connectivity. VANETs are considered as a special class of mobile ad hoc networks (MANETs).

The most challenging issues in VANET is the high mobility and the frequent changes of the network topology. The topology of vehicular networks could vary when the vehicles change their velocities and/or lanes. These changes depend on the drivers, road situations and traffic status, and are not scheduled in advance. The proposed routing protocols and mechanisms that may be employed in VANETs should adapt to the rapidly changing topology. Besides that, they must be efficient and provide quality of Service (QOS) support to permit different transmission priorities according to the data traffic type. The existing routing protocols as they are designed for MANETs are not suitable for VANETs. Vehicular Ad Hoc Network (VANET) is a new challenging network environment that pursues the concept of ubiquitous computing for future. They are a special form of mobile ad hoc networks (MANETs) that provide vehicle-to vehicle communications. It can be thought as each vehicle is equipped with a wireless communication facility to provide ad hoc network connectivity. VANETs tend to operate with-out an infrastructure; each vehicle in the network can send, receive, and relay messages to other vehicles in the network. This way, vehicles can exchange real-time information, and drivers can be informed about road traffic conditions and other travel-related information.

VANETs have unique and fascinating features, different from other types of MANETs, such as normally higher computational capability, higher transmission power, and some kind of predictable mobility, with comparison with general MANETs. VANETs bring lots of possibilities for new range of applications which will not only make the travel safer but faster as well. Reaching to a destination or getting help would be much easier. The concept of VANETs is quite simple by incorporating the wireless communication and data sharing capabilities .VANETs are also similar to MANETs in many ways. Both networks are multi-hop mobile networks having dynamic topology. There is no central entity, and nodes route data themselves across the network. Both VANET and MANET are rapidly deployable, without intense of an infrastructure.

Objective

The objective of this paper is to propose a novel evolving graph-based reliable routing scheme for VANETs.

****Corresponding author: Khan Anam,***
VIT ME pursuing, Mumbai, India.

Considering that vehicles travel at high speeds on highways, the data delivery service could have many disruptions due to frequent link breakages. It is very important to ensure that the most reliable links are chosen when building a route. The major contributions of this paper are given here.

Special characterstics for vanets

Similar to MANETs, the network nodes in VANETs are self-organized and can self-manage information in a distributed fashion without a centralized authority or a server dictating the communication. It means that nodes can act as servers and/or clients at the same time and exchange information with each other. Moreover, VANETs have unique attractive features over MANETs as follows (Feng *et al.,* 2008)]: _ Higher transmission power and storage – The network nodes (vehicles) in VANETs are usually equipped with higher power and storage than those in MANETs. _ Higher computational capability – Operating vehicles can afford higher computing, communication and sensing capabilities than MANETs. _ Predictable mobility - Unlike MANETs, the movement of the network nodes in a VANET can be predicted because they move on a road network. If the current velocity and road trajectory information are known, then the future position of the vehicle can be predicted.

Equations

The traffic dynamics in terms of aggregated macroscopic quantities such as traffic density p(x, t), traffic flow q(x, t), and average velocity v(x, t) as a function of space x and time t corresponding to partial differential equations. These parameters can be related together by their average values using the following relations: (Mahmoud Hashem Eiza and Qiang Ni, 2013)

$$d_{m}=\frac{1000}{\rho_{veh}}-l_m \qquad \text{.... I}$$

$$q_m=\frac{1}{\tau_m}=v_m\left(\frac{1}{\frac{1000}{\rho_{veh}}-l_m}\right) \qquad \text{....II}$$

$$\tau_m=\frac{d_m}{v_m}=\frac{1}{v_m}\left(\frac{1000}{\rho_{veh}}-l_m\right) \qquad \text{....III}$$

where dm is the average distance between vehicles (in meters), _veh is the traffic density on the freeway section considered (in vehicles per kilometer), lm is the average length of vehicles (in meters), _m is the average time gap between vehicles (in seconds), vm is the average velocity of vehicles on the road (in kilometers per hour), and qm is the average traffic flow (in vehicles per hour). This approach can be used to describe both general traffic flow status and individual vehicles (Mahmoud Hashem Eiza and Qiang Ni, 2013).

Vanet orinted evolving graph model

We propose the VoEG model to address the evolving properties of the VANET communication graph and consider the reliability of communications links among vehicles. We associate the following 2- tuple (t, rt (e)) with each edge, where t denotes the current time, and rt(e) = rt(l) denotes the link reliability value at this time *t*, as defined in (8). In the VoEG model, the communication link between two vehicles is not available if its reliability value rt(e) is equal to zero. Let e = {A,B} be a link in the VoEG, where VVoEG is the set of vertices and EVoEG is the set of links. Let Trav(e) be a function that determines whether this link e can be

$$Trav_{(e)}=\begin{cases}True, & if\ 0<r_t(e)\leq 1\\ False, & r_t(e)=0\end{cases} \qquad \text{....XI}$$

Fig. 1(a) shows the VoEG status and the corresponding reliability values associated to each link at t= 0 s. All links are eligible to be traversed because ce dEVoEG, Trav(e) = true.

Fig. 1: Proposed VoEG model at (a) *t* = 0 s and (b) *t* = 5 s.

Fig. 1(b) shows the VoEG status at t = 5 s,

where the associated links' reliability values change due to the evolution of the VoEG. It can be noticed that edges {B,E} and {F,G} are now not eligible to be traversed,

i.e., Trav ({B,E})=Trav({F,G}) = false at t = 5 s,

where r5({B,E})=r5({F,G})=0.[2]

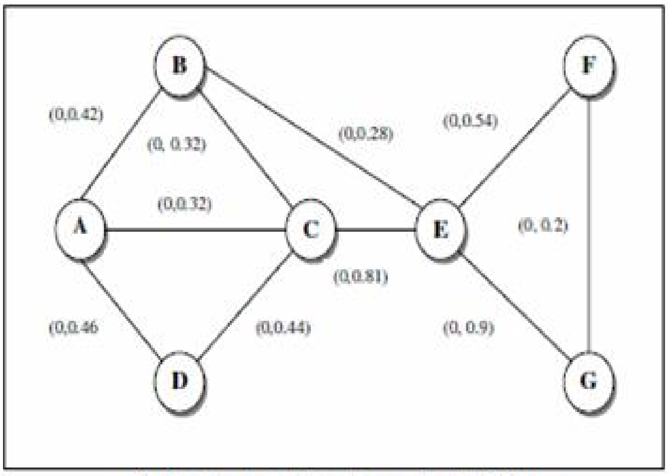

fig 1 (a): Vanet oriented evolving graph model (VOEG)

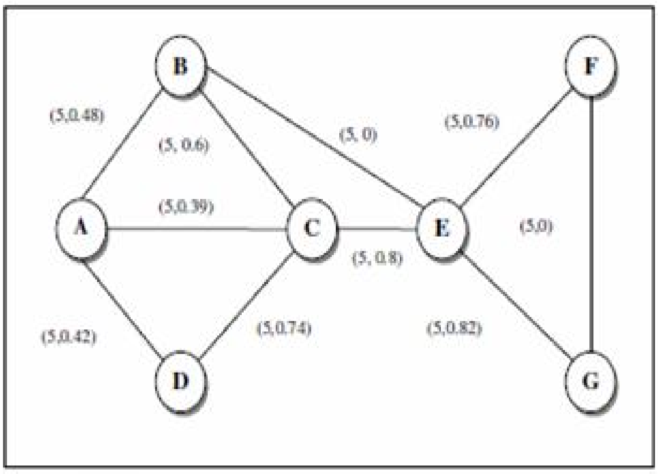

fig 1 (b): Vanet oriented evolving graph model (VOEG)

EG-DIJKSTRA

Finding the most reliable route in the VoEG model is equivalent to finding the MRJ. The normal Dijkstra algorithm

(Cormen *et al*., 1990) cannot be directly applied in this context. It modified and propose the evolving graph Dijkstra's algorithm (EG-Dijkstra) to find the MRJ based on the journey reliability definitions in (Feng *et al.,* 2008) . The proposed EG-Dijkstra algorithm maintains an array called the reliable graph (RG) that contains all vehicles and their corresponding MRJ values. EG- Dijkstra starts by initializing the journey reliability value RG (sr) = 1 for the source vehicle and RG (u) = φ for other vehicles. A pseudo code for the EG-Dijkstra algorithm is: Input: A VoEG and a source vehicle sr.

Output: Array RG that gives the most reliable routes from sr to all other vehicles.

Variables: A set Q of unvisited vehicles.

1. Set route reliability RG (sr) = 1 and RG (u) = φ for all other vehicles;
2. Initialize array Q by inserting sr;
3. While Q is not empty do

(a) x ←the vehicle with highest reliability value in Q;
(b) Mark x as visited vehicle;
(c) For each open neighbor v of x do

i. If Trav (e) is True
1. Set RG (v) ← rt(e) × RG(x);
2. Insert v if not visited in Q;

(e) Close x;

4. Return the array RG; (Mahmoud Hashem Eiza and Qiang Ni, 2013)

Route Discovery Process in Eg-Raodv

When a network node needs a connection, it broadcasts a routing request (RREQ) message to the neighboring vehicles. Every node receives this RREQ will record the node it heard from and forward the request to other nodes. This procedure of recording the previous hop is called backward learning. If one of the intermediate nodes has a route to the destination, it replies back to the source node with that route. If more than one reply arrives at the source node, then it uses the route with the least number of hops. If the routing request arrives at the destination node, a routing reply (RREP) message is sent back to the source node using the complete route obtained from the backward learning. When a link breakage occurs, routing error messages (RERR) are generated to repair the existing route or discover a new one.

A pseudocode of the EG-RAODV route discovery process is illustrated.

Input: A VoEG and a source vehicle sr and a destination vehicle de.

Output: The MRJ from sr to de.

1. Get VoEG current status using the prediction algorithm
2. Calculate the reliability value for all links in VoEG model.
3. MRJ ← EG-Dijkstra(VoEG, sr);
4. While the MRJ is not empty

(a) x ← the first node from the MRJ;
(b) Record x in the RREQ header as extension;
(c) Remove x from the MRJ;

4. Send an RREQ from sr to de along the MRJ;
5. While an RREP is not received, wait;
6. Start sending data; (Mahmoud Hashem Eiza and Qiang Ni,2013)

Performance Metrics

Four performance metrics are considered for the

1. Packet delivery ratio (PDR): It represents the average ratio of all successfully received data packets at the destination node over all data packets generated by the application layer at the source node.
2. Link failures: It represents the average number of link failures during the routing process. This metric shows the efficiency of the routing protocol in avoiding link failures.
3. Routing Requests Ratio: It expresses the ratio of the total transmitted routing requests to the total successfully received routing packets at the destination vehicle.
4. Average end-to-end (E2E) delay: It represents the average time between the sending and receiving times for packets received.

Advantges

1. It Increases the Road Safety by providing the proper signal to the drivers on the road.
2. It Provides the reliable Route to the drivers to avoid traffic congestion and also road accidents.
3. It increases the evaluation of communication technique.

Conclusions

In this paper, the graph theory is extended and VoEG model is proposed. A new EG-Dijkstra algorithm was developed to find the MRJ in the proposed VoEG. Was designed and formalized EG-RAODV routing protocol to provide a reliability-based routing scheme for VANETs. The EG-RAODV achieves the highest PDR and it obtains the lowest routing request ratio because the broadcasting technique is not needed in the route discovery process. As it chooses the most reliable route to the destination, it achieves the lowest number of link failures and the lowest average E2E delay values.

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