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Edge Node Based Greedy Routing for VANET with Constant Bit Rate Packet Transmission

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***Abstract* -- VANETs (Vehicular Ad hoc Networks) are highly mobile wireless ad hoc networks and will play an important role in public safety communications and commercial applications. Routing of data in VANETs is a challenging task due to rapidly changing topology and high speed mobility of vehicles. Conventional routing protocols in MANETs (Mobile Ad hoc Networks) are unable to fully address the unique characteristics in vehicular networks. In this paper, we propose EBGR (Edge Node Based Greedy Routing), a greedy position based routing approach to forward packet to the node present in the edge of the limited transmission range of forwarding node as most suitable next hop, with consideration of nodes moving in the direction of the destination. This paper presents a detailed description of our approach and also discusses the improvement in terms of packet delivery ratio compared to current routing protocols.**

***Index Terms* -- Vehicular Ad hoc Networks, Highly Dynamic Topology, Greedy Position Based Routing, EBGR**

I. INTRODUCTION

Vehicular Ad hoc Networks (VANETs) are based on short-range wireless communications (e.g., IEEE 802.11) for the use in road safety and many other commercial applications. The Federal Communications Commission (FCC) has allocated 75 MHz in 5.9 GHz band for licensed Dedicated Short Range Communication (DSRC) for vehicle-to-vehicle and vehicle to infrastructure communications. The radio range of VANETs is several hundred meters, typically between 250 and 300 meters. It is expected that more vehicles would be equipped with computing and wireless communication devices in the near future. We assume that vehicles should be equipped with wireless communication devices, GPS, digital maps, and optional sensors for reporting vehicle conditions. Vehicles exchange information with other vehicles as well as road-side infrastructures within their radio ranges.

A vehicular network is a mobile ad hoc network and its characteristics can be summarized as high dynamics, mobility constraints, predicable mobility, large scale and energy constraints are not that high as every vehicle has a large enough battery capacity.

II. RELATED WORK

The various routing protocols of MANET and VANET are analyzed ([1] – [12]) and drawbacks of those routing protocols are described in the Table 1.

TABLE 1
DRAWBACKS OF ROUTING PROTOCOLS IN MANET AND VANET

Routing protocols	Drawbacks
AODV (MANET)	▪ Large latency of packet transmission.
DSR (MANET)	▪ Large latency of packet transmission.
OLSR (MANET)	▪ High bandwidth consumption due to dynamic topology.
GPSR (MANET)	▪ Frequent network disconnection. ▪ Routing loops. ▪ Too many hops. ▪ Routing in wrong direction.
GSR (VANET)	▪ End to end connection is difficult in low traffic density.
GPCR (VANET)	▪ End to end connection is difficult in low traffic density.
A-STAR (VANET)	▪ Routing paths are not optimal and results in large delay of packet transmission
MDDV (VANET)	▪ Large delay if the traffic density varies by time.
VADD (VANET)	▪ Large delay due to varying topology and varying traffic density.
PDGR (VANET)	▪ Too many hops. ▪ Large Delay if the traffic density is high. ▪ Low Packet delivery ratio. ▪ Frequent network disconnection.

III. PROPOSED ROUTING ALGORITHM

A. Edge Node Based Greedy Routing Algorithm (EBGR):

The EBGR (Edge Node based Greedy Routing) algorithm is designed for sending messages from any node to any other node (unicast) or from one node to all other nodes (broadcast) in a mobile ad hoc network. The general design goals of the EBGR algorithm are to optimize the packet behavior for ad hoc networks with high mobility and to deliver messages with high reliability.

The EBGR algorithm has three basic functional units. First is the Neighbor Node Identification (NNI) algorithm, second is the Node Direction Identification (NDI) algorithm and the third is Edge node Selection (ENS) algorithm. The NNI algorithm is responsible for collection of information of all nodes present within the transmission range of source/forwarder node at any time. NDI algorithm is responsible to identify the direction of motion of nodes which is moving towards the direction of destination. The ENS algorithm is responsible for selection of the specific edge node within limited transmission range for further forwarding of a particular packet.

In the following section, the general assumptions that the EBGR algorithm is based on are first briefly discussed. Then, the NNI algorithm, NDI algorithm and ENS algorithm are discussed.

B. Assumptions

The algorithm design is based on the following assumptions,

- All nodes are equipped with GPS receivers, digital maps, optional sensors and On Board Units. Location information of all vehicles/nodes can be identified with the help of GPS receivers.
- The only communications paths available are via the ad-hoc network and there is no other communication infrastructure.
- Node power is not the limiting factor for the design.
- Communications are message oriented.
- The Maximum Transmission Range (MTR) of each node in the environment is 250m.

C. Neighbor node identification (NNI) Algorithm:

Neighbor node identification is the process whereby a vehicle/node identifies its current neighbors within its transmission range. For a particular vehicle, any other vehicle that is within its radio transmission range is called a neighbor. All vehicles consist of neighbor set which holds details of its neighbor vehicles. Since all nodes might be moving, the neighbors for a particular mobile node are always changing. The neighbor set is dynamic and needs to be updated frequently. Generally, neighbor node identification is realized by using periodic beacon messages. The beacon message consists of node ID, node location and timestamp. Each node informs other nodes of its existence by sending out beacon message periodically.

- Inform all nodes within the transmission range of source/packet forwarding node to intimate its presence by sending a beacon message every μ second.
- After the reception of a beacon, each node will update its neighbor set table.
- If a node position is changed, then it will update its position to all neighbors by sending beacon signal.
- If a known neighbor, times out after $\alpha * \mu$ seconds without having received a beacon (α is the number of beacons that a node is allowed to miss) and it will be removed from the neighbor set table.

D. Node Direction Identification (NDI) Algorithm:

In Node Direction Identification algorithm, the potential score of all nodes present within the limited transmission range (LTR) of source/packet forwarding node is calculated. The potential score is calculated to identify the direction of motion of nodes .The appropriate edge node with largest potential score will be considered as moving towards the destination node D and that particular node can be chosen as next hop to forward the packet to the destination node D. Potential score is calculated by mathematical model represented in Fig.1.

$$PS_i = \rho \times \left(1 - \frac{D_i}{D_c}\right) + \omega \times \cos\left(\overrightarrow{v_i}, \overrightarrow{l_{i,d}}\right)$$

Here,
PS_i : *Potential score of node i*
ρ, ω : *Two potential factors*
Let $\rho + \omega = 1$ *and* $\rho > \omega$
D_i : *Shortest distance from edge node i to destination D.*
D_c : *Shortest distance from packet forwarding node c to destination D.*
$\frac{D_i}{D_c}$: *Closeness of nexthop.*
$\overrightarrow{v_i}$: *Vector for velocity of edge node i.*
$\overrightarrow{l_{i,d}}$: *Vector for the location of edge node i to the location of destination node D.*
$\cos(\overrightarrow{v_i}, \overrightarrow{l_{i,d}})$: *Cosine value of angle made by these vectors*

Fig. 1: Mathematical model of NDI Algorithm

A large cosine value implies a vehicle/node can still approach the destination closer and closer along its current direction.

E. Edge Node Selection (ENS) Algorithm:

In the Edge Node Selection algorithm ([13], [14]), edge nodes are selected for packet forwarding event. An edge node is a node which has shortest distance to the destination D compared to all other nodes within the limited transmission range of source/packet forwarding node. The LTR is considered to avoid packet loss during packet transmission to edge node in MTR. An edge node has the responsibility of saving received packet/packets in forwarding table and transfers it later when those nodes meet new neighbors. The overall objective is to forward the message as far as possible and as soon as possible while minimizing the total number of nodes involved in packet transmission and to avoid packet loss.

The MTR of a vehicle/node is 250m.The limited transmission range is considerably less than MTR. The limited transmission range comprises different levels which includes,

- Level1 transmission range (i.e.L1TR=200m)
- Level2 transmission range (i.e.L2TR=150m)
- Level3 transmission range (i.e.L3TR=100m)
- Level4 transmission range (i.e.L4TR=50m).

LTR is calculated by the formula,

$$\text{LTR} = \left(\frac{80}{100}\right) \times \text{MTR}$$

In Fig.2, the detailed pseudo code of ENS algorithm is illustrated.

MTR: $Maximum\ Transmission\ Range = 250m$
L1TR: $Level1\ Transmission\ Range\ =\ 200m$
L2TR: $Level2\ Transmission\ Range\ =\ 150m$
L3TR: $Level3\ Transmission\ Range\ =\ 100m$
L4TR: $Level4\ Transmission\ Range\ =\ 50m$
currentnode: *the current packet carrier*
$\boldsymbol{loc_c}$: *the location of current node*
$\overrightarrow{v_c}$: *speed vector for current node*
dest: *destination of the packet*
$\boldsymbol{loc_d}$: *the location for destination*
nextHop: *the node selected as next hop*
$\boldsymbol{neigh_i}$: *the* ***i****th neighbor*
$\boldsymbol{loc_i}$: *the location of the* ***i****th neighbor*
$\overrightarrow{v_i}$: *the speed vector of the* ***i****th neighbor*
$loc_c \leftarrow getLocation(currentnode)$
$\overrightarrow{v_c} \leftarrow\ getSpeed(currentnode)$
$loc_d\ \leftarrow\ getLocation(dest)$
$D_c = distance(loc_c\,, loc_d)$
$\overrightarrow{l_{c,d}} = loc_d\ -\ loc_c$
$PS =\ \omega \times \cos\,(\overrightarrow{v_c}, \overrightarrow{l_{c,d}}\,)$
$nextHop = currentnode$
for all *neighbors of currentnode* ***do***
$loc_i \leftarrow getLocation(\ neigh_i\ )$
$\overrightarrow{v_i}\ \leftarrow\ getSpeed(neigh_i)$
$D_i\ =\ \ distance(loc_d\,, loc_i)$
$D_{ci}\ =\ \ distance(loc_c\,, loc_i)$
for all *neighbors of currentnode with* D_{ci} ***do***
if $(D_{ci}\ <\ L1TR\ \ \&\&\ D_{ci}\ >L2TR)$
$\overrightarrow{l_{i,d}} = loc_d\ -\ loc_i$
$PS_i =\ \rho \times \left(1 - \frac{D_i}{D_c}\right) +\ \ \omega \times \cos\,(\overrightarrow{v_i}, \overrightarrow{l_{i,d}})$
for $neigh_i$ *with greater* PS_i ***do***
$PS =\ PS_i$
$nextHop = neigh_i$
end for
else if $(D_{ci}\ <\ L2TR\ \ \&\&\ D_{ci}\ >L3TR)$
$\overrightarrow{l_{i,d}} = loc_d\ -\ loc_i$
$PS_i =\ \rho \times \left(1 - \frac{D_i}{D_c}\right) +\ \ \omega \times \cos\,(\overrightarrow{v_i}, \overrightarrow{l_{i,d}})$
for $neigh_i$ *with greater* PS_i ***do***
$PS =\ PS_i$
$nextHop = neigh_i$
end for
else if $(D_{ci}\ <\ L3TR\ \ \&\&\ D_{ci}\ >L4TR)$
$\overrightarrow{l_{i,d}} = loc_d\ -\ loc_i$
$PS_i =\ \rho \times \left(1 - \frac{D_i}{D_c}\right) +\ \ \omega \times \cos\,(\overrightarrow{v_i}, \overrightarrow{l_{i,d}})$
for $neigh_i$ *with greater* PS_i ***do***
$PS =\ PS_i$
$nextHop = neigh_i$
end for
else if $(D_{ci}\ <\ L4TR)$
$\overrightarrow{l_{i,d}} = loc_d\ -\ loc_i$
$PS_i =\ \rho \times \left(1 - \frac{D_i}{D_c}\right) +\ \ \omega \times \cos\,(\overrightarrow{v_i}, \overrightarrow{l_{i,d}})$
for $neigh_i$ *with greater* PS_i ***do***
$PS =\ PS_i$
$nextHop = neigh_i$
end for
else
carry the packet with currentnode
end if
end for
end for
if nextHop $\neq$ *currentnode then*
forward the packet to nextHop
else
carry the packet with currentnode
end if

Fig. 2: Pseudo code for ENS Algorithm

The position information of neighbor nodes and destination node D is obtained using the GPS.The distance between the current node and its neighbor nodes are calculated using information obtained from GPS.

IV. Simulation Results and Analysis

Among the routing protocols we aforementioned, we choose GPSR, PDGR and EBGR for comparison. So in this section, we evaluate the performance of GPSR, PDGR and EBGR in an open environment.

A. Manhattan Mobility model:

We use Manhattan mobility model to simulate the movement pattern of moving vehicles on streets or roads. The road is composed of a number of horizontal and vertical streets along with highways. The mobile node is allowed to move along the grid of horizontal and vertical streets. At an intersection of a horizontal and a vertical street, the vehicle can turn left, right or go straight with certain probability.

The simulation is performed using NCTUns 5.0 [15], a novel vehicular network simulator tool. The GUI of NCTUns 5.0 supports the desired road network construction and road information is stored in road network specification file.GUI allows to specify different car profile setting and it is stored in car profile file. The movement of vehicles is controlled by setting vehicle movement and information related to this is stored in node movement scenario configuration file. The simulation parameters are specified in Table 2.

TABLE 2
Simulation Parameters

Parameter	Value
Simulation Area	2400m * 2400m
Number of Vehicles	40 - 140
Average speed of vehicles	15 – 60 (km/hr)
Number of packet Senders	30
Transmission Range	250m
Constant Bit Rate	2 (Packets/Second)
Packet Size	512 Bytes
Vehicle beacon interval	0.5 (Seconds)
MAC Protocol	802.11 DCF
Simulation Time	500s

B. Performance Metrics to evaluate simulation:

Packet delivery ratio (PDR):

The ratio of the packets that successfully reach destination.

$$PDR = \frac{Total\ number\ of\ packets\ \ delivered}{Total\ number\ of\ packets\ transferred} \times 100$$

C. Packet Delivery Ratio:

In this part, we compare the performance of GPSR (Greedy Perimeter Stateless Routing Protocol), PDGR (Predictive Directional Greedy Routing Protocol), and EBGR (Edge Node Based Greedy Routing) in terms of packet delivery ratio. We will show how packet delivery is affected by the data transmission density and traffic density. Fig. 3 shows the packet delivery ratio as a function of Constant Bit Rate (CBR) and compares the performance under different vehicle traffic densities. As shown in Fig. 3, with the fixed CBR, GPSR have smaller packet delivery ratio. But the underlying reasons are different. For GPSR, it is because the routing is along the pre-selected path. Especially, when the vehicle density is low, fewer vehicles will be available for next hop along a specific path. When the vehicle density becomes higher, where the connectivity is much better, all routing strategies achieves better delivery ratio, since more nodes can be met to forward packets.

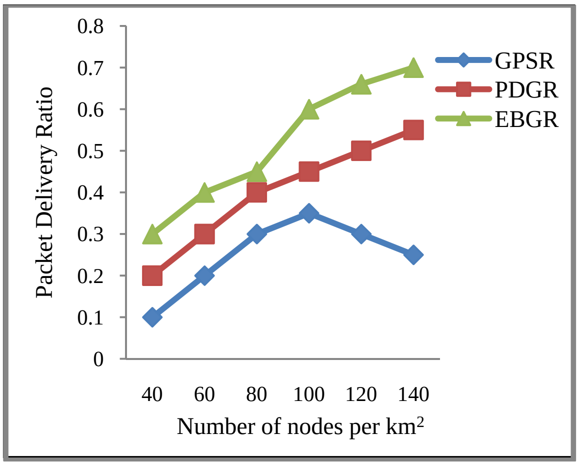

Fig. 3: Packet delivery ratio for fixed CBR

PDGR outperforms GPSR in terms of packet delivery ratio when the vehicle density is high. Since PDGR have restriction on the routing path and employ direction probing in routing, it will forward packet only to its 2 hop neighbors which is closer to the destination and moving toward the destination. But it doesn't guarantee the delivery of packet to the node present in the edge of the transmission range of forwarding node, which is considered as most suitable next hop, due to high dynamics of vehicles. In EBGR, a node will forward its packet to the node present in the edge of its limited transmission range which is moving towards the destination and also store and forward the packet if no node present in the transmission range. In EBGR, the packet delivery ratio is directly proportional to the node density. When the number of nodes is increased, automatically packet delivery ratio is also increased. With prediction, EBGR can slightly outperform PDGR in packet delivery ratio.

V. Conclusion

In this paper we have investigated routing aspects of VANETs. We have identified the properties of VANETs and previous studies on routing in MANETs and VANETs. We have commented on their contributions, and limitations. By using the uniqueness of VANETs, we have proposed a new position based greedy routing approach EBGR. Our simulation results have shows EBGR outperform GPSR and PDGR significantly in the terms of packet delivery ratio. In the future, our approach requires modifications by taking into account the city environment characteristics and different mobility models. Comparison of proposed EBGR approach with other existing approach shows that our routing algorithm is comparatively better than other routing protocols in packet delivery.

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