Mixed model routing for VANET to handle city road and rural areas

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Abstract: Currently vehicular ad hoc network (VANET) is emerging backbone for communication in roads. It can be used for exchanging traffic information and emergency information from the controlling authority of the vehicle. But efficient routing in VANET is very difficult as because of mobility of the vehicle. The wireless links in this network are highly error prone and can go down frequently due to mobility of nodes, interference and less infrastructure. Therefore, routing in ad hoc network in general and VANET in particular is a critical task due to highly dynamic environment. Most of the existing routing protocols are designed for wired and structured network. Cost of sending routing updates is much greater in a wireless network than in a wired network. Managing stable route with less number of routing updates is very difficult to achieve. On the other hand, if routing updates sent too often, it will be wastage of battery of mobile car nodes and channel bandwidth.

Therefore, adopting these protocols in VANET is very difficult if not impossible. Another problem is road structure differs from place to place. In most of the urban area roads have road side unit. But rural interior area does not have road side unit. As per different proposed model's topology rapidly changes with time. Main challenge in situation is to maintain the routing path, reduce the overhead and reduce the delay. In our proposed work we have suggested a model where roadside unit logically form a doubly link list in urban area. Each RSU controls the vehicular nodes near to its geographic proximity. The interior places which does not have RSU, is taken care by using cluster-based communication. These two structures are interconnected to manage the total communication scenario. This proposed model is much more robust to take of all possible routing situations.

Keywords **- VANET, RSU, PCBR, GPS.**

1. INTRODUCTION

Basic routing protocols are broadly classified into two groups: Reactive and Proactive [1]. Proactive routing protocols periodically exchanges information whereas On-demand. Reactive routing protocols exchange information among the nodes as and when required. In ad hoc network environment uniqueness of this protocol lies with the fact that it should take care of the zones with road side unit as well as without road side unit.

2 Ad hoc Network Routing Protocols:

Several routing protocols those have been designed so far but most of them are applicable for the wired and structured network. Due to its special nature it is very difficult to adopt those protocols in ad hoc mobile network which are usually applicable for wired network.

Vehicular ad hoc networks(VANET) is one of the most popular type of mobile ad hoc networks. The communication in vehicular network are of two types, communication between vehicles and communication between vehicle and road side unit. The earliest work in VANET was started in 19890s.

The communication requirement in VANET is not only to avoid accident but also for sharing congestion information [2][3]. Better communication is very much dependent upon the routing policies adopted there. There are many routing policies but most of them suffers from inefficiency. This inefficiency is mostly generated due to high mobility of the vehicle. Our proposed structure in this direction can handle situation with and without road side units.

2.1 Proactive or Table-driven approach:

In Table driven approach routing information is stored and maintained from a database table that is why it is sometimes called a table-driven protocol [4]. From application point of view, it has minimum initial time delay to establish the desired route.

2.2 Reactive Routing on demand routing protocol:

In on demand routing approach, the source and destination nodes exchanges information as and when required. The source node initiates the route [5]. In fact, the on-demand routing protocol is much more reliable in comparisons to proactive Routing.

3. Previous work

AODV routing protocol: In Ad Hoc On Demand Distance Vector (AODV) (Perkins, 1999) routing, upon receipt of a broadcast query (RREQ), nodes record the address of the node sending the query in their routing table [6]. This procedure of recording its previous hop is called backward learning. Upon arriving at the destination, a reply packet (RREP) is then sent through the complete path obtained from backward learning to the source. At each stop of the path, the node would record its previous hop, thus establishing the forward path from the source. The flooding of query and sending of reply establish a full duplex path. After the path has been established, it is maintained if the source uses it. A link failure will be reported recursively to the source and will in turn trigger another query-response procedure to find a new route.

AODV+PGB routing protocol: Preferred Group Broadcasting (PGB) (Naumov, 2006) is a broadcasting mechanism that aims to reduce broadcast overhead associated with AODV's route discovery and to provide route stability especially important in VANETs where fast moving vehicles are used as wireless hosts. Based on the received signal of the broadcast, receivers can determine whether they are in the preferred group and which one in the group to broadcast. Since only one node can broadcast and since the preferred group is not necessarily the one that makes the most progress towards the destination, route discovery might take longer than before. Another drawback is that broadcast can discontinue if the group is found to be empty (possibly because of sparse networks). Packet duplication can happen as two nodes in the preferred group can broadcast at the same time. According to Naumov et al. (2006), the way to deal with broadcast duplication is to add packet's predecessors into the packet. This creates the same type of overhead in the packet as DSR.

Dynamics Source Routing(DSR): It is also a powerful on-demand routing protocol. It has two main aspects
(a) Route Discovery
(b) Route Maintenance

DSR is an on-demand ad hoc network routing protocol consisting of two parts: Route Discovery and Route Maintenance. In DSR, [7] when a node has a packet to send to some destination and does not currently have a route to that destination in its Route Cache, the node starts a Route Discovery procedure; this node is known as the initiator or source node of the Route Discovery and the destination of the packet is known as the Discovery's target or destination. The initiator transmits a ROUTE REQUEST packet by broadcasting to its neighbors. In the ROUTE REQUEST packet, the initiator specifies the target and a unique identifier from the initiator. Each node receiving the ROUTE REQUEST, if it has recently seen this request identifier from the initiator, discards the REQUEST. Otherwise, it appends its own node address to a list in the REQUEST and rebroadcasts the REQUEST. When the ROUTE REQUEST reaches its target node, the target sends a ROUTE REPLY back to the initiator of the REQUEST, including a copy of the accumulated list of addresses from the REQUEST. When the REPLY reaches the initiator of the REQUEST, it caches the new route in its Route Cache. Route Maintenance is the mechanism by which a node sending a packet along a specified route to some destination detects if that route has broken, for example because two nodes in it have moved too far apart. DSR is based on source routing: when sending a packet, the originator lists in the header of the packet the complete sequence of nodes through which the packet is to be forwarded. Each node along the route forwards the packet to the next hop indicated in the packet's header and attempts to confirm that the packet was received by that next node; a node may confirm this by means of a link-layer acknowledgment, passive acknowledgment, or network-layer acknowledgment. If, after a limited number of local retransmissions of the packet, a node in the route is unable to make this confirmation, it returns a ROUTE ERROR to the original source of the packet, identifying the link from itself to the next node as broken. The sender then removes this broken link from its Route Cache; for subsequent packets to this destination, the sender may use any other route to that destination in its Cache, or it may attempt a new Route Discovery for that target if necessary.

Zone Routing Protocol(ZRP)

ZRP is a hybrid scheme of both proactive and reactive approaches [8]. In fact, both proactive and reactive approaches have their own merits and demerits. In the ZRP the advantages of both the proactive and reactive protocols have been adopted for the optimum performance. ZRP itself provides the framework for other protocols to be operative. It is believed that ZRP itself is not a routing protocol.
Both purely pro-active and purely reactive routing protocols have their own advantages and disadvantages. The Zone Routing Protocol (ZRP) is a combination of both the strategies. In this hybrid scheme advantages of both paradigms have been adopted for optimal performance. The ZRP is not an independent functioning protocol rather; it provides a foundation for other protocols. The separation of a nodes local neighborhood from the global topology of the entire network allows for applying different approaches - and thus taking advantage of each technique's features for a given situation. These local neighborhoods are called zones (hence the name); each node may be within multiple overlapping zones, and each zone may be of a different size. The ``size" of a zone is not determined by geographical measurement, as one might expect, but is given by a radius of length p, where p is the number of hops to the perimeter of the zone. By dividing the network into overlapping, variable-size zones, ZRP avoids a hierarchical map of the network and the overhead involved in maintaining this map. Instead, the network may be regarded as flat, and route optimization is possible if overlapping zones are detected. While the idea of zones often seems to imply similarities with cellular phone services, it is important to point out that each node has its own zone and does not rely on fixed nodes (which would be impossible in MANETs).

TORA routing protocol: Temporally Ordered Routing Algorithm (TORA) (Park, 2007) routing belongs to a family of link reversal routing algorithms where a directed acyclic graph (DAG) toward the destination is built based on the height of the tree rooted at the source [9]. The directed acyclic graph directs the flow of packets and ensures reachability to all nodes. When a node has a packet to send, it broadcasts the packet. Its neighbor only broadcasts the packet if it is the sending node's downward link based on the DAG.
A node would construct the directed graph by broadcasting a query packet. Upon receiving a query packet, if a node has a downward link to the destination, it will broadcast a reply packet; otherwise, it simply drops the packet. A node, upon receiving a reply packet, will update its height only if the height from the reply packet gives the minimum of all the heights from reply packets it has received so far. It then rebroadcasts the reply packet. The advantages of TORA are that the execution of the algorithm gives a route to all the nodes in the network and that it has reduced far-reaching control messages to a set of neighboring nodes. However, because it provides a route to all the nodes in the network, maintenance of these routes can be overwhelmingly heavy, especially in highly dynamic VANETs.

In all the above-mentioned routing protocols route discovery and maintenance overhead is high. Furthermore, mobility factor is high in VANET environment, which leads to the frequent network partitioning and route disconnection. In-addition many of these protocols creates lot of redundant messages in the network, which leads to congestion and delay in data transfer. The broadcast-based routing protocols suffers from hidden node problem and collision of messages.
Our proposed work is free from these drawbacks because vehicles are portioned into bunches of vehicle. Each bunch of vehicle is under the control of one RSU. The RSU's are in fixed link structure. Rural areas are efficiently managed by by cluster-based communication. So as a hole total system manages all possible situations efficiently.

4 Technique and methodology:

According to our current model we assume VANET as collection of Road Side unit (RSU) and collection of vehicle under the control of those RSU. So, the total picture of the system can be depicted as in the fig-1

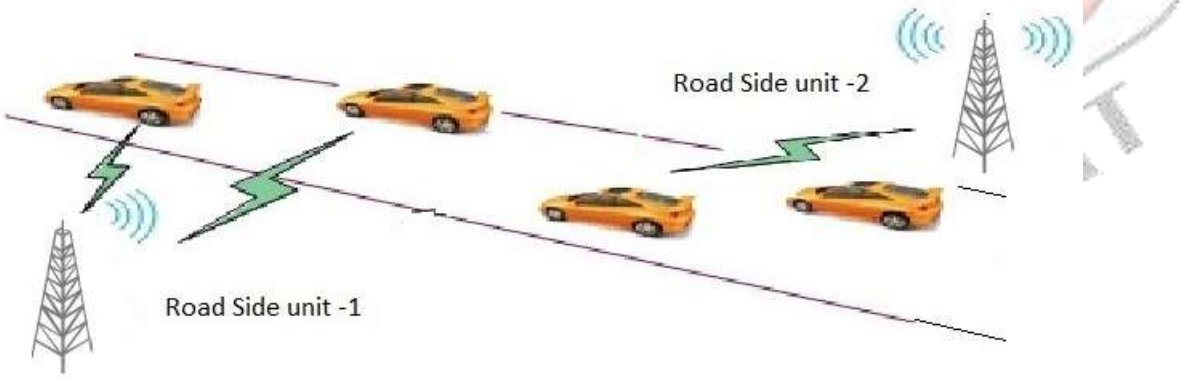

Fig-1

We propose a data structure where each RSU is considered as a node in a link list. In this data structure, RSU nodes are connected through doubly link list. This link is taken care by the wireless link between two consecutive RSU. Moreover, each RSU act as a root to all the vehicle within its wireless range. All vehicle has pre-installed GPS system and the list of RSU with their corresponding position. So, at any moment of time a vehicle can find its controlling RSU by checking its GPS position and the RSU in the closest proximity. So, this is the way the handoff can be tackled easily.
We categorize the communication procedure into three categories:

i) RSU to RSU
ii) RSU to vehicle
iii) Vehicle to vehicle

Details of time complexity of the above three categories:

i) RSU to RSU communication: It is basically transfer of information between two nodes in doubly link list. So maximum time taken will be O(n) where n is the total number of RSU units.

ii) RSU to vehicle communication: According to our model it can be executed in O(n+1) time which is equivalent to O(n).

iii) Vehicle to vehicle communication: If both the vehicle belongs under the control of same RSU, communication time will be constant. But if the two vehicle belongs under different RSU, the worst-case complexity for message transfer can be O(n) because it can have to travel total chain of RSU's.

In our proposed model each RSU node contains following information:

i) Node's unique identity
ii) Pointer to next node
iii) Pointer to previous node
iv) Array of pointers to the vehicles under its control
v) Pointer to buffers for storing messages
vi) Data to store the GPS location of the vehicles

With this model vehicles and RSU can exchange message to form a proper VANET structure. Let us call link this list of the RSU's as RSU-chain. This model will fail to work where RSU's are not present. But at geographically interior location RSU may not be present. So those locations cannot be managed with the current system.
These interior locations can be managed well by cluster-based communication system. So, for these interior locations we suggest cluster-based network for vehicles. Each cluster will be identified by cluster head. The end node of the RSU-chain will be connected to the closest cluster head in wireless range of that RSU.

Now the structure of the total system becomes as in fig-2 below:

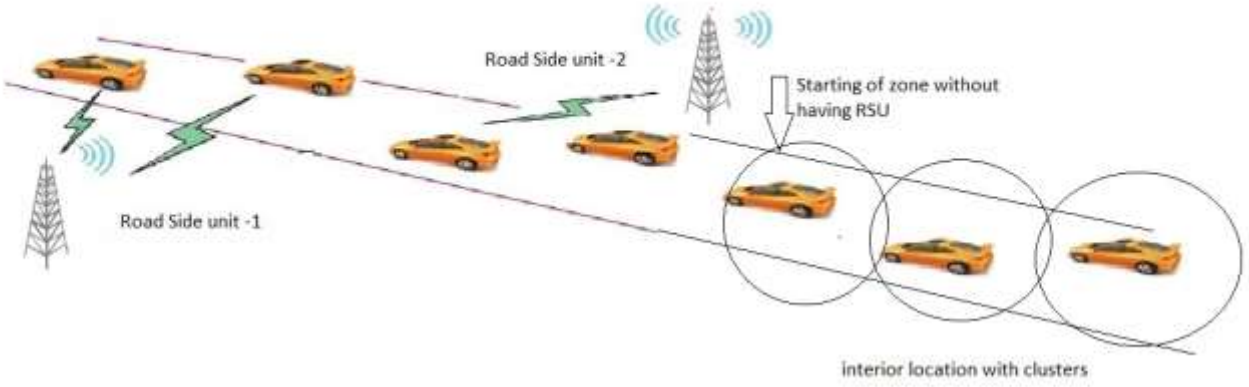

Fig-2

So, a part of our architecture uses Clustered Based Routing Protocol [10]. We assume in this part of VANET we do not have any road side unit. We have already utilized this type of cluster structure for different purpose [11].

Clustering requires minimal setup time for formation of the cluster of vehicles. In any given network only, a subset of the total number of nodes need to forward a route request. Cluster based routing identifies a set of nodes that it recognizes as redundant for forwarding route request queries. This is possible because the formation of cluster relives some nodes from taking part in the Route Request Mechanism. In this way we have a less numbers of nodes participating in broadcasting the packets.

The structure of the cluster and the inter communication between the vehicle can be made in the following way:

Node state in a cluster:

Nodes are grouped into clusters based on their proximity to each other. A cluster can have three types of nodes, namely cluster head, gateway and ordinary nodes. Ordinary nodes never forward broadcast requests. All nodes in a network, which are within hearing range of some other node, can be reached with this cluster formation. Every node can assume five external states, namely, INITIAL, CLUSTERHEAD, FULL GATEWAY, DISTRIBUTED GATEWAY and ORDINARY NODE (as shown in Figure. 3).
A representative of each cluster is named as a cluster head. A node belonging to two clusters simultaneously is called a gateway. Thus, message from any node can reach any other node within the same cluster with two hops.
At cold start, all nodes, upon start up, set their state to INITIAL. A node wishing to transmit data, broadcasts a Route Request packet to seek out the destination host. Any other node in its hearing range, which is in INITIAL state, receives this packet and changes its own state to CLUSTER HEAD READY. When the CLUSTER HEAD READY node transmits the packet, it sets its state to CLUSTER HEAD. All nodes within the range of this CLUSTER HEAD become members of this cluster. If there is another CLUSTER HEAD in the vicinity or two nodes simultaneously declare themselves as CLUSTERHEADs, then one of them relinquishes its state based on a rule called Lowest ID. The Lowest ID rule states that among two or more nodes that compete for the state of CLUSTERHEAD the node with the lowest id retains its state and the others must relinquish their state as CLUSTERHEAD. (Every mobile node is assigned a unique identifier number.) As a packet traverses the network at cold start, the network
of INITIAL nodes gets partitioned into well-defined clusters. Member nodes that can hear from two or more cluster heads declare themselves as FULL GATEWAYS. Member nodes of a cluster that can hear from member nodes of another cluster become DISTRIBUTED GATEWAYS. All other member nodes change their state to ORDINARY NODE.

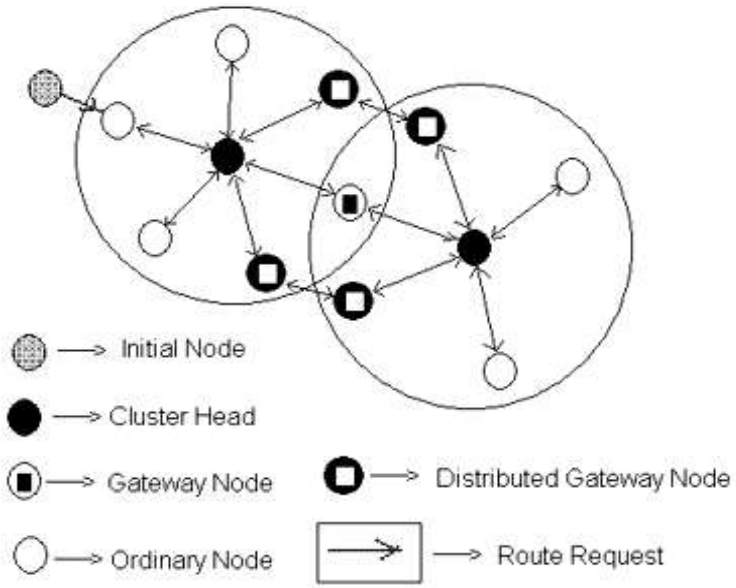

Fig-3

In our design the clusters will communicate in the following way:

1. Gateway node and cluster head both will maintain list of all cluster nodes. As gateway is member of multiple cluster it will maintain the list under different cluster head as they physically belong. Now if source and destination both belongs to same cluster packets will be sent through cluster head and gateway's will ignore the packets as it knows the fact that the destination belongs to same cluster by checking the list of nodes it maintains.

2. If the destination belongs to different cluster than that of the source, then source will send the initial packet to its cluster head. Cluster head will broadcast the massage within the cluster. This massage will be received and processed by the gateways and other node will remain silent. Gateways will forward the first packet to next gateway through adjacent cluster head but before sending puts it's IP address in data part of the packet in sequential manner. This procedure will go on until the first packet reaches the destination. We will avoid cycle and loop back in the path by following this list. From the second packet onward, we will keep this list in the header part of the packet for the rest of the communication. The gateways will process the packets for forwarding or ignore it depending upon whether its own IP address belongs next in the sequence or not. The overhead of

this list will not be too much as the number of hops from source to destination will not be very big for an ad-hoc network forming a LAN. If a node (gateway, ordinary node or cluster head is lost we must restore the path.

3. Our approach will maintain a sequence number for the packets during the total communication between a source and destination. This will avoid confusion regarding the state of the nodes which exists in PCBR.

4. Our approach will also maintain a session number which is fixed during total communication between source and destination. The path loss is very frequent in ad hoc network due frequent movement of the nodes. This number sometime will help in case of path restoration.

5. If the cluster head doesn't receive any packet for predetermined amount of time, cluster head will send dummy packets to all the members of the cluster and must be replied by all the members of the cluster. This will help the clusters to keep intact in low load and cartel the name of the nodes which are not existing members of the cluster.

With this proposed routing system, we have the following objectives in our mind

I) Share congestion information between vehicles
II) Broadcast catastrophic information
III) Identify traffic violation etc.

At any point of time we want that the congestion in the road should be within control. Keeping this objective in mind we can mathematically model the situation as follows:

$$Cu = Lu * Wu * fsu * fhvu$$
$$Cd = Ld * Wd * fsd * fhvd$$

Where Cu and Cd are two parameters to measure the car density in up and down direction. Lu and Ld are road length taken for consideration. Fsu, Fsd, Fhvu, Fhvd are frequency of small and heavy vehicles in up and down directions respectively.
Here our objective is to is to keep Cu and Cd less than a limit, say Maxu and Maxd. The region under a RSU which crosses this limit is identified as congested. The vehicles watching this information can divert their route in advance. In cluster-based regions where RSU's are not present congestion is identified by vehicle density within a cluster. Broadcasting catastrophic information is just a message broadcast with help of this network. As the total system is under a network chain it can be manages easily be realized. Each RSU receiving this type of information broadcast it so that message can reach to all the vehicles under its control.

Conclusion and Future Scope

In our current proposal we have suggested a communication network for the vehicle. The proposed model can handle communication urban area with road side unit and the interior area without road side unit. The model is robust and can handle the current day needs. However, the security of the messages should be taken care properly. So, the secure communication for the proposed model can be developed in future. This will make the communication procedure more reliable.

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