Congestion-assessment and Hybrid Routing Protocol for Vehicular Ad Hoc Network

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Abstract

In vehicular ad hoc network (VANET), nodes have to cooperate to forward each other's packets through the networks. Every node, including source and intermediate nodes, has a fair opportunity to transmit a packet. Consequence, the hot spot may incur traffic congestion. The packet loss rate and the transmission delay are increased, but the throughput is decreased. On account of the contention for the shared channel, the throughput of each single node is limited not only by the channel capacity, but also by the transmissions in its neighborhood. Additionally, the network throughput still restrict by the channel capacity. Some other related works using multiple channels simultaneously to transmit packets without interfering each other increases the throughput. But if the traffic load is heavy, these schemes may trigger off more serious packet loss on the contrary because they do not consider the congestion problem especially in VANET environment. In this paper we use cross layer approach to design routing protocol for VANET with aim to restrict the number of packets of every flow passing by congested nodes. Firstly, we estimate congested probability at each node by using MAC overheads, quality of link, and data rate. Subsequently, we use congested probability assessment as route metric. This method enhances link stable and network throughputs. For building routing protocol operation we use hybrid model (inherit good characteristics from proactive and reactive routing protocols). It helps restrict route overheads and fast convergence of route discovery process. The simulation results illustrate our prominent proposed routing protocol.

Keywords: *VANET, congestion-assessment, hybrid routing protocols*

1. Introduction

In VANET, nodes density has a great impact on the performance by influencing some factors such as capacity, routing efficiency, delay, and robustness [1, 2].Waves of traffic jams, whether caused by constraints in the transportation network, traffic controls, or fluctuations in speed, cause the network's density to vary from one location to another, thus disturbing the homogeneous distribution of nodes [3]. Moreover, the abrupt and frequent change in density creates a highly dynamic topology. This topology change would cause severe degradation to the network's performance [1, 3, 4]. Another important constraint in the multi-hop inter-vehicular communications is the limited bandwidth within such environment [5, 3, 6]. Actually, the wireless channel can be occupied by competitive nodes for many reasons, such as collisions, interferences, insufficient signal strength, duration of the transmission sequence, *etc.*

To deal with this environment constraints, and in order to ensure safe and optimized communication architecture (to guarantee required services on a "best effort" network), the establishment of a quality of service policies becomes mandatory, which is involved in handling congestion within developed routing protocols for VANET [1-8].

In [9] M. Moinuddin Bhuiyan and Muhammad Jaseemuddin proposed a congestion-aware overlay networks. The authors focus on Peer-to-Peer (P2P) network design, which is a form of overlay network where each node only maintains information of its neighbor overlay nodes, shares its resources and contents, and forwards data on behalf of other nodes. Since every node can act as a server and provide services to other nodes, there is no single point of failure in the P2P network. They have considered to link instability and power constraints on each node by modifying resource-aware overlay networks [10]. Their gain is the mitigation effect of file download traffic on the query forwarding performance in P2P forming transactions. It is not suitable applied for density and contention-base networks as VANET.

Xiaoqin Chen et al proposed a congestion-aware routing protocol in [11]. The authors considered to congestion-aware routing metric which employs data-rate, MAC overhead, and buffer queuing delay, with preference given to less congested high throughput links to improve channel utilization. Subsequently, they nominated the Congestion Aware Routing protocol for Mobile ad hoc networks (CARM). CARM applies a link data-rate categorization approach to prevent routes with mismatched link data-rates. The crucial gain of authors reseach work is mitigation congestion on each node in network. But in that protocol, the authors only focus on utilizing weighted channel delay for selecting high throughput routes with low congestion depend on residual abilities of each node. The more general scenarios of congested restriction are not mentioned.

In this paper we consider to both aspect of congestion in network. Firstly, we explore congested probability at each node through MAC overheads, quality of link, and data rate. These information supports routing layer building stable route and hight throughput links. Subsequently, we consider congestion in general scenario by selecting nodes with good residual communicable ability to build anchor nodes for routing in network.

Remain of our paper is divided in to four parts. The next part is the related works. This part deal with an overview of routing protocols for VANET. The third part is the proposed routing protocol. In this part we solve aforementioned problems by our proposed algorithms. The fourth part is simulation results and analysis. It illustrates our proposed routing protocol operated results comparing with AODV operated results. The last part is conclusion.

2. Related Works

This part we summarize some main attributes of routing protocol for VANET. It is the background of our proposed routing protocol.

In VANET each node can be seen as hosts and routers. As hosts, nodes need to provide user-oriented services; as routers, nodes need to run the routing protocols, in accordance with routing strategies, nodes involve packet forwarding and router maintenance. When the source nodes and destination nodes have the requirement of communication, and they are not within the scope of wireless transmission, then they run the routing protocols by other nodes, and send data by wireless multi-hop approach.

According to the different driver models of route discovery, routing protocols for VANET can be divided into proactive and reactive routing protocol. Combined with the advantages of these two types of routing protocols is the hybrid routing protocol.

- *Proactive routing protocols*

In proactive routing protocols, because each node must retain the latest routing table in the local network; so, when network topology changes, routing changes must be send to each node in order to obtain the consistent and up-to-date network routing. These kinds of routing protocol adapt to the requirements of VANET through the modification of existing routing protocols.

This kind of routing protocol requires each node to update immediately when there is any change in the network. For example, updates information only contain changes of the routing, or updates the entire routing table, which is affected by very fast change of the topology. Therefore, proactive routing protocol requires system's resources very much. But whenever a node requires setup the communication it can setting up a link to destination immediately.

- *Reactive routing protocols*

Reactive routing protocol initiates a routing request that is based on the specific needs of communications, instead of periodically broadcasting routing information packet. Therefore, it only performs routing operations when the node need route, maintains the routing in the communication process, deletes routing when there is no communication in long time. These mechanisms make reactive routing save network resources effectively. Therefore, this kind of routing protocol is more suitable for VANET than proactive routing protocol.

- *Hybrid routing protocols*

Hybrid routing protocol combines advantages of the proactive routing and the reactive routing. It protects the more accurate routing information in the local scope by the use of reactive routing. By the use of proactive routing in further distance routing, it will reduce the overhead of overall routing protocol. Thus, it can play a better network performance; such agreements are more applicable to topology in special scenes, such as highly dynamic changes.

3. Proposed Routing Protocol

In VANET, when the traffic is heavy or there are a large number of greedy users, these problems would lead to poor throughput. Congestion occurs when the limited buffer space is full, and the subsequent data has to be dropped. So our proposed routing protocol was come from an idea to build a routing protocol can meet of the requirements about robust link between nodes, improving system performance, and uses minimum network resources and reliable in multi-rate network. For improving link between nodes, and system performance we use MAC overheads, quality of link, and data rate of each node measuring congested probability, and use it as parameters to build the routing metric. For minimum network resources and most suitable for VANET scenario we use hybrid routing protocol in our model.

3.1. Congestion probability measurement

Estimating MAC overhead

In this part, we consider a network using IEEE 802.11 [12] MAC with the distributed coordination function (DCF). In such networks, the standard packet sequence is: request-to-send (RTS), clear-to-send (CTS), data, acknowledgement (ACK). The amount of time between the receipt of one packet and the transmission of the next is called a short interframe space (SIFS). So, the channel occupation due to MAC contention will be

$$C_{occ} = t_{RTS} + t_{CTS} + 3t_{SIFS} \quad (1)$$

where t_{RTS} and t_{CTS} are the time consumed on Request To Send and Clear To Send, respectively and t_{SIFS} is the Short Inter Frame Space period. The MAC overhead is hence calculated using the equation (2)

$$M_{oh} = C_{occ} + t_{acc} \quad (2)$$

where t_{acc} is the time taken due to access contention.

Estimating quality of the link

It is possible to forecast the link quality and discard the links with the lower signal strengths from the route selection using the received signal strength from the physical layer. When a sending node broadcasting RTS packet, it piggybacks its transmissions power, P_t . On receiving the RTS packet, the intended node measures the signal strength received which holds the following relationship for free-space propagation model. For estimating quality of the link the below equation (4) is used.

$$P_r = P_t(\lambda/4\pi d^2).G_t.G_r \quad (3)$$
$$QoL = P_r \quad (4)$$

where λ is the wavelength carrier, d is distance between sender and receiver, G_t and G_r are unity gain of transmitting and receiving omni directional antennas, respectively. The effects of noise and fading are not considered.

Estimating data rate

In VANET, throughput through a given route is depending on the minimum data rate of its entire links. In a route of links with various data rates, when a high data rate node forwards more traffic to a low data rate node, there is a chance of congestion. This leads to long queuing delays in such routes. Since congestion considerably reduces the effectual bandwidth of a link, the link data-rate is computed by the equation (5)

$$D_{rate} = D_{size} / C_{delay} \quad (5)$$

where D_{Size} is the data size and C_{delay} is the channel delay.

Congestion-assessment function

In this part, we measure congestion probability within each node at time i through MAC overheads, QoL, and D_{rate} parameters. The congestion aware assessable function (6) which involves computational efficiency and accuracy is defined as

$$f_i = \frac{1}{QoL.M_{oh}.D_{rate_i}} \quad (6)$$

where f_i represents the fitness value of the i^{th} data packet, QoL is the quality of the link, M_{oh} is the MAC overheads, D_{rate_i} is the data rate at time i, it is already using for $(i+1)^{th}$ transaction. The fitness value of each node at time i was selected for building route metric in our proposed routing protocol.

3.2. Proposed routing protocol

We use fitness value of each node at time i information as route matric, and define set "*anchor neighbor*" of each node in the network. Node q is the neighbor of node k, and node q become anchor neighbor of node k if only if $f_{q_i} \leq F_{k\_avr_i}$ where f_{q_i} is the fitness value of node q at time i, $F_{k\_avr_i}$ is the average of node k's neighbor's fitness values. Therefore, we have set of anchor neighbors of node k ($ANBN_k$) as

$$ANBN_k = \{\text{node } q \mid (\text{node } q \text{ is the neighbor of node } k) \,\&\, (f_{q_i} \leq F_{k\_avr_i})\} \quad (7)$$

Route discovery strategy

Route discovery strategy is divided two phases. The first phase is the process to look for a destination node in the neighbor table. If Destination node is in neighbor table then the Source node sends RREQ to Destination node by using unicast, and Destination node replies RREP to Source node also by using unicast. After that the link between Source node and Destination node is setting up, the route discovery process is finished. If Destination node is not in neighbor table then the route discovery process changes to second phase. In the second phase of route discovery, the Source node sends address of Destination node and its *not_anchor* nodes to *anchor* nodes by using multicast. The Destination node address is for next node to continue discovery process to find Destination node. Its *not_anchor* node address is for restricting routing overhead in next steps. In next step of route discovery process, each node in the set of anchor neighbor node continues performing the route discovery process from the first phase. It finished when setting up route to the Destination node.

Parameters used in routing discovery process algorithm at one node are:

OVH_NBR: Number of overhead neighbor,

OVH_ANC_NBR: Number of overhead anchor neighbor,

RREQ_NUM: Number of allowable RREQ packets,

$Node_i$_address: IP address of node i.

```
IF node_k receives a requirement to connect to node_q
THEN {
FOR (i=0; OVH_NBR -1; i++)
{IF neighbor_address == node_q_address THEN {
Send (Addr, RREQ); exit}
ELSE {
FOR (j=0; OVH_ANC_NBR-1; j++)
{Send (Addr, RREQ); RREQ_Number++}
} } }
```

Algorithm.Route Discovery

where Send(Addr, RREQ) is a function to send RREQ message to next node, Addr is address of Destination nodes. If Addr is only one address, it uses unicast. If Addr includes all of anchor neighbor, it uses multicast. If Addr includes all of neighbor, it uses broadcast. But in our proposed routing protocol not uses broadcast method. When Destination node received the RREQ, it can use Reply(RREP) function. Reply is a function to send RREP message back to prior node of current node. If prior node is intermediate node, it continues used Reply(RREP) to send RREP message to its prior node. This operation repeat until RREP reached Source node.

Protocol operation

For built the neighbor table, this protocol operation is the same as proactive routing protocol. One node uses "Hello" packet to maintain the relationship with neighbor nodes. If there is any a new node in it's the propagative range, this node is using "Hello" packet to update information of the new node. Therefore, neighbor table of each node in network always was updated instantaneously. The protocol operations were illustrated in Figure 1.

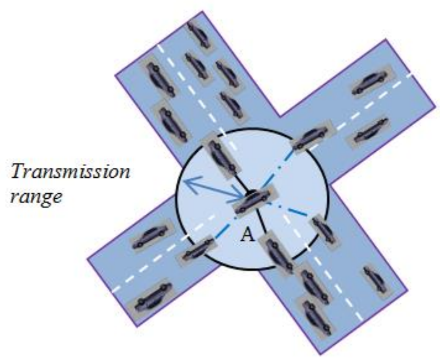

Figure 1. Node A uses "hello" packet for updating and maintaining information of neighbor nodes, ↔ denotes the transmission range of node A

The rest of the protocol is similar to reactive routing protocol, but there is one modification. When Source node receives a requirement to send message to Destination node, first steps it look for Destination node address in neighbor table. If Destination node is in neighbor table, it uses send (Addr, RREQ) send RREQ to Destination node, and Destination node uses reply (RREP) reply RREP to Source node and discovery process is finished. If Destination node is not in neighbor table, Source node sends RREQ to close neighbor node. This operation restricts the routing overhead the same as OLSR [13]. Furthermore, it is a condition will be sure the setting up route will be rapid convergence and reliable.

4. Simulation Result and Analysis

In this part we show preliminary results comparing between our proposed congestion-assessment and hybrid routing protocol (CAHRP) and one popular protocol AODV. We use the developed module in ns-2.34 [14] with support of Monarch [15] to simulate CAHRP, and AODV in the same condition of performance. The network was selected with the number of nodes varying from 50 to 200. Nodes are randomly distributed over 1000m x 1000m area. Send/receive data packets between Source node and Destination node use the IEEE 802.11g, uses IEEE 802.11 DCF for channel access, and data packet size is set to 512 bytes. Each routing protocol was deployed in the same scenario for run simulation.

Obviously, from Figure 2 the time for route discovery is directly proportional to nodes. But our proposed routing protocol CAHRP was more slowly increase than AODV. The time for each step in route discovery can shrink by using the better of *QoL* and data rate for building route matric and relaying destination node to ‘anchor neighbors’ mechanism. In Figure 3, it is observed that end-to-end data transfer time inversely proportional to nodes. But we can see end-to-end data transfer time decreases very fast in CAHRP.

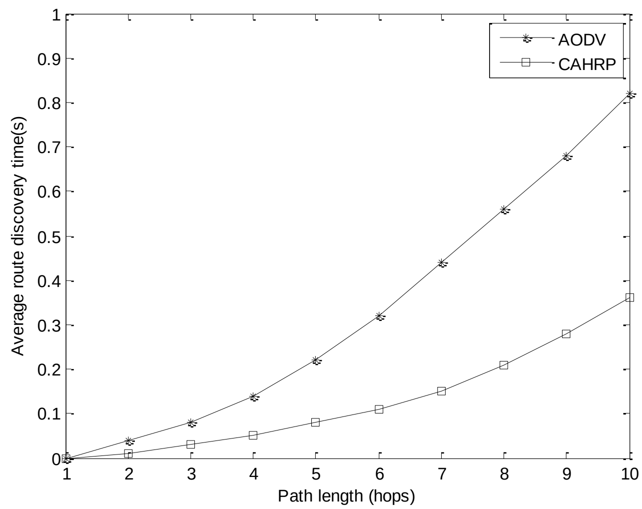

Figure 2. Average route discovery time

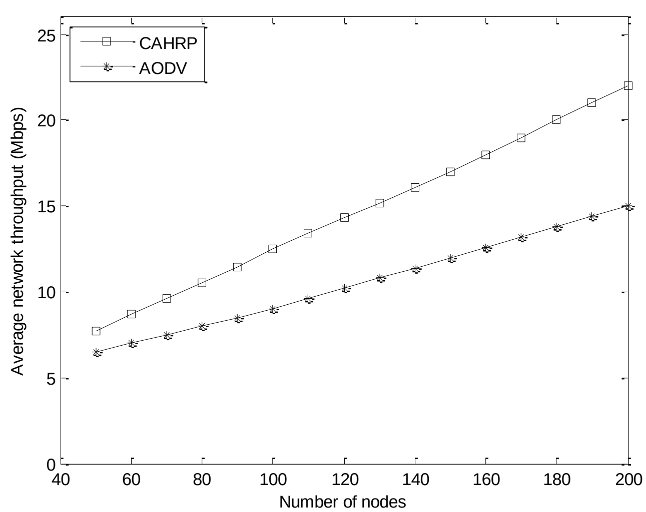

Figure 3. Average end-to-end data transfer time

As inevitable results, the optimal delay time in route discovery and end-to-end data transfer time made CAHRP gain outstanding performance. It is illustrated in Figure 4 and Figure 5 with measuring network throughput and packet loss rate parameters.

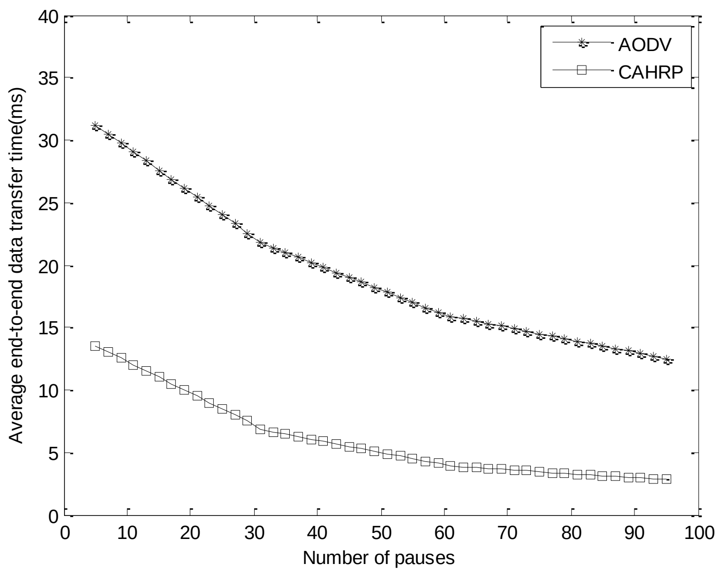

Figure 4. Average network throughput

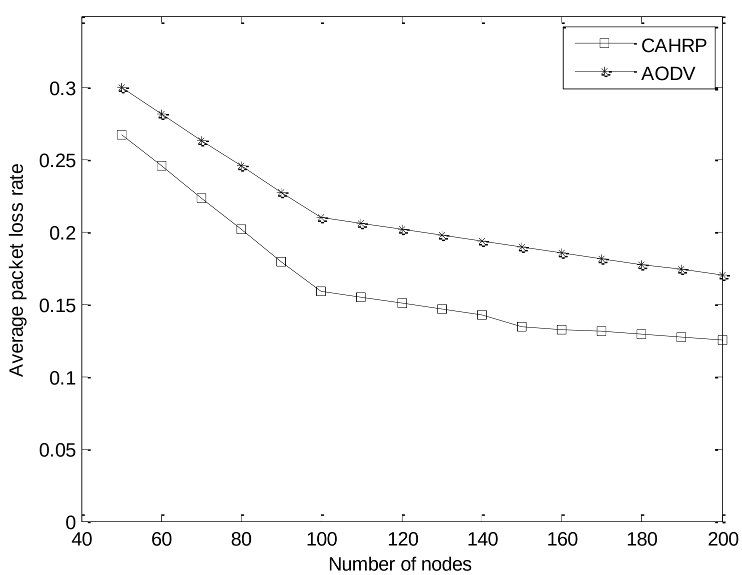

Figure 5. Average packet loss rate

5. Conclusion

In this paper we proposed a proper routing protocol for VANET. By building route matric incorporate MAC overheads, quality of link and data rate, it makes links more stable and high throughput. Furthermore, it restricts numerous excessive route overheads by using only anchor neighbor nodes within each step for building routes from source to destination. With using unicast, multicast and broadcast mechanisms appropriately, it reduces significantly control overheads and processing overheads. Therefore, it meets the communication requirements as fast setting up connection link, reliable link, reducing broken link, and increasing network throughput in VANET environment.

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