CROSS LAYER USING END-TO-END DELAY ASSESSMENT FOR ROUTING PROTOCOL IN VEHICULAR AD HOC NETWORK

Le Van Minh\textsuperscript{a,b}, Yang MingChuan\textsuperscript{a}, and Guo Qing\textsuperscript{a}

\textsuperscript{a}Communication research center, Harbin Institute of Technology, Harbin, China
\textsuperscript{b}Faculty of Information Technology, Vinh University, Viet Nam
minhhdvinh@gmail.com, mcyang@hit.edu.cn,qguo@hitcrc.hit.edu.cn

ABSTRACT

The moving with fast velocity of each node in vehicular ad hoc network (VANET) results in the existence transient communication links, which degrade the performance of developed protocols. Established routes frequently become invalid, and existing communication flows are interrupted, incurring delay and additional overhead. In this paper we use cross layer approach solving these problems. Firstly, we concentrate on measurement end-to-end delay in VANET. Subsequently, we use the end-to-end delay assessment of medium access control (MAC) layer for building route metric in network layer with the aim of shrinking route discovery time. For deploying route model we use hybrid routing protocol (combined between proactive and reactive routing protocol) aiming reduce route overhead, accelerate route convergence speed, and enhance route quality in routing table in each node. The simulation results illustrate outstanding features of our proposed model.

Keywords: Vehicular ad hoc network; routing protocol; end-to-end delay; cross layer approach.

1 INTRODUCTION

The VANET includes mobile nodes communicated each other without any infrastructure or central administration. These characters make VANET becoming a huge challenge, and attract tremendous attention of researchers in recently. One of the foremost challenges in vehicular networks is to design protocols that can handle the high mobility of vehicles and constant changes in the underlying topology.

Due to high mobility of VANET, the wireless link between two vehicles is short-lived. The channel quality information from physical and MAC layer help the sender in predicting the link connection time; subsequently the sender can find a new receiver before the current link is disconnected. Thus cross-layer interaction between MAC layer and higher layers is desirable to maintain link connectivity and improve system performance. We consider this works in some proposed routing protocols. In [1] the authors proposed the Movement Prediction-based Routing (MOPR) protocol. They used movement prediction information of each vehicular for V2V communication in VANET. It improves the routing process by taking the vehicle movement information that is typically available in MAC layer such as position, direction, speed, and network topology into consideration. Based on such vehicular information, MOPR predicts the future location of intermediate relay nodes, which can subsequently be used to estimate the life-time of point-to-point links.

Similar to MOPR, Xi Yu et al. proposed a reliable routing protocol for VANET named AODV-VANET. They use Total Weight of the Route (TWR) between the source and destination nodes [2]. TWR comprise not only Vehicle Speed and Vehicle Movement Direction but also Link Quality between Vehicles. In fact, they modify Ad hoc On-Demand Distance Vector (AODV) [3] parameters by complement speed, direction of vehiculars and expiration time estimation with the aim of achieving better routing performance.

Although MOPR and AODV-VANET consider link quality information for improving routing process, their gain is a minor adjustment. Obviously, in dense vehicular environment the multi-path routing is more predominant than single-path routing. Therefore, these protocols need consider route selection in urban environment.

As two aforementioned protocols our proposed routing protocol also use end-to-end delay information available in MAC layer for building routes. But our proposed routing protocol considers route selection by using hybrid routing model. The rest of the paper is divided into four parts. In the
second part we stage out summary of routing protocol for vehicular ad hoc network. It comprise proactive, reactive, and hybrid routing protocol. The third part is our proposed routing protocol. In that we first measure end-to-end delay, subsequently use that result for building route metric of our proposed routing protocol. The fourth part we present some simulation results of our model. The fifth part is the conclusion of paper.

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.

  The proactive 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

As we mentioned above, the crucial features of VANET include rapid changing of topology, high mobility, high probability of network partitions, and end-to-end connectivity could not be guaranteed. So our proposed routing protocol was come from an idea to build a routing protocol can meet of the requirements about minimum routing delay time, uses minimum network resources and reliable in multi-rate network. For minimum routing delay time we use end-to-end delay estimation 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 End-to-end delay assessment and routing metric

The packet processing delay at each node includes the processing time at the individual layers and the inter-layer communication time at various levels [4]. Therefore, the Node Processing Time (NPT) is

\[
NPT = Pd_A + ILCd_{AT} + PdT + ILCd_{TN} + OvNLd + ILCd_{NM} + OvMACLd + ILCd_{MP} + Pd_p
\]

(1)

where \(Pd_A\) is the processing delay at the application layer, \(ILCd_{AT}\) represents the inter-layer communication delay be-tween the application layer and the transport layer, \(PdT\) denotes the processing delay at transport layer, \(ILCd_{TN}\) represents the inter-layer communication delay between the transport layer and the network layer, \(OvNLd\) denotes the overall delay at the network layer, \(ILCd_{NM}\) represents the inter-layer communication delay between the network layer and the MAC layer, \(OvMACLd\) denotes the overall delay at the MAC layer, \(ILCd_{MP}\) represents the inter-layer communication delay between the MAC
layer and the physical layer, and \( PdP \) denotes the processing delay at physical layer.

In our works we use delayed information from \( ILCd_{NM} \), \( OvMACLd \), and propagation for building routing metric. Therefore, node processing time able to consider as

\[
NPT = ILCd_{NM} + OvMACLd + ILCd_{MP} + PdP
\]

(2)

The MAC transmission delay depends on the backoff mechanism of the MAC protocol, and the average number of retransmissions required for a packet to be successfully transmitted. If \( i \) is the average number of retransmissions required for a successful packet transmission, then the amount of time spent by the MAC layer in transmitting this packet over the channel (\( OvMACLd \)) is given as [5], [6]

\[
OvMACLd = \sum_{j=0}^{i-1} \left( DIFS + \frac{CW_j - 1}{2} \cdot \text{slot} + \text{RTS} + \mu + SIFS \right) + DIFS
\]

\[
+ \frac{CW_j - 1}{2} \cdot \text{slot} + \text{RTS} + \text{CTS} + \text{DATA} + \text{ACK} + 4 \cdot \mu + 3 \cdot SIFS
\]

where \( RTS \) is the time spent in the RTS packet transmission, \( CTS \) is the time spent in the CTS packet transmission, \( DATA \) is the time spent in the data transmission, \( ACK \) is the time spent in the acknowledgement transmission, \( SIFS \) is the short inter-frame space, and \( \mu \) is the propagation delay.

Assume that the source and destination are separated by an average of \( n \) hops we have

\[
TotMACLd = n \cdot OvMACLd
\]

(4)

\[
Tot\mu = n \cdot \mu \cdot \text{Avg}
\]

(5)

The average time spent for a packet transmission depends on the average number of retransmissions required for successfully transmitting a packet. Therefore, if \( i+1 \) is the average number of attempts for the successful transmission of a packet, then the time spent by the MAC layer for transmitting a single RREQ packet (\( RREQ1Pkt \)) in the four-way handshake transmission is given by (3), where the DATA represents an RREQ packet. If the average number of route discovery processes required to be initiated to obtain a route to the destination is \( nRREQs_{avg} \), then the total time spent in the route discovery processes (\( RREQT_{tot} \)) is given by

\[
RREQT_{tot} = (RREQ1Pkt + RREP_{out}) \cdot nRREQs_{avg}
\]

(6)

where \( RREP_{out} \) is the average RREP time-out period at the network layer. We have an estimative end-to-end delay formula as

\[
EEdRDT = RREQT_{tot} + TotMACLd + Tot\mu
\]

(7)

The end-to-end delay information was assessed by formula (7). We use this information as route matrix, and define set “close neighbor” of each node in the network. Node \( j \) is the neighbor of node \( i \), and node \( j \) become close neighbor of node \( i \) if only if \( EEdRDTij \leq EEdRDT \text{avg} \) where \( EEdRDTij \) is end-to-end delay time between node \( i \) and node \( j \). \( EEdRDT \text{avg} \) is the average end-to-end time delay between node \( i \) and it’s neighbors. Therefore, we have set of close neighbor of node \( i \) (\( CNBN_i \)) as

\[
CNBN_i = \{ \text{node j} \mid \text{(node j is the neighbor of node} \ i) \ \& \ \text{(EEdRDTij} \leq \text{EEdRDT} \text{avg}) \}\]

(8)

### 3.2 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 far nodes to close nodes by using multicast. The Destination node address is for next node to continue discovery process to find Destination node. Its far node address is for restricting routing overhead in next steps. In next step of route discovery process, each node in the set of close 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,
- \( OVH\_CLS\_NBR \): Number of overhead close neighbor,
- \( RREQ\_NUM \): Number of allowable RREQ packets,
- \( \text{Node}_i\_address \): IP address of node \( i \).

```
IF node\_i receives a requirement to connect to node\_j
THEN {
    FOR (i=0; OVH\_NBR -1; i++)
        IF neighbor\_address == node\_i\_address THEN {
            Send (Addr, RREQ); exit}
ELSE {
```


FOR (j=0; OVH_CLS_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 for unicast. If Addr includes all of close neighbor, it uses for multicast. If Addr includes all of neighbor, it uses for 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.

3.3 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: One node uses “hello” packet for updating and maintaining information of neighbor nodes.

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 [7]. Furthermore, it is a condition will be sure the setting up route will be rapid convergence and reliable.

4 SIMULATION RESULTS
In this part we show preliminary results comparing between our proposed routing protocol EEDAHRP (end-to-en delay assessment and hybrid routing protocol) and one popular protocol AODV. We use the developed module in ns-2.34 [8] with support of Monarch [9] to simulate EEDAHRP, 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 EEDAHRP was more slowly increase than AODV. The time for each step in route discovery can shrink by using end-to-end delay assessment for route matric and relaying destination node to ‘close 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 EEDAHRP.

Figure 2: Average route discovery time.
As inevitable results, the optimal delay time in route discovery and end-to-end data transfer time made EEDAHRP gain outstanding performance. It is illustrated in figure 4 and figure 5 with measuring network throughput and packet loss rate parameters.

5 CONCLUSION

In this paper we proposed a proper routing protocol for VANET. By using end-to-end delay information for building route metric, it shrinks route discovery time and makes building route rapid convergence. Furthermore, it inherits the advanced properties of proactive routing protocol and reactive routing protocol. With using unicast, multicast and broadcast mechanisms appropriately, it reduces significantly control overhead and processing overhead. Therefore, it meet 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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6 REFERENCES