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Robust Multi-path Routing for Vanet Based on Mobility Prediction

[1]Guangsong Yang, [1]Xinwang Zheng, [1]Chaoyang Chen and [2]Lianfen Huang
[1]School of Information Engineering, Jimei University, Xiamen 361021, China
[2]School of Information Technology and Science Xiamen University, Xiamen 361005, China

Abstract: Routing of data in a Vehicular *Ad hoc* Network (VANET) is a challenging task due to the high dynamics of such a network. Multi-path routing protocol is an effective solution. The influence of backup routes on the multi-path routing performance is analytically investigated. In order to enhance the robustness of the network, AOMDV multi-path routing protocol is modified by limiting the number of backup paths and predicating node mobility, NS2 simulation in realistic mobility models show that it can select more stable link and improve the network performance.

Key words: Vehicular *Ad hoc* network (VANET), mobility prediction, multi-path routing

INTRODUCTION

Vehicular *Ad hoc* Network (VANET) is a kind of network designed for V2V (vehicle-to-vehicle) communication, It is an important part of Intelligent Transportation System (ITS) and is being widely researched in recent years (An *et al*., 2011). VANET has some specific characteristics such as no energy resource constraint, high mobility patterns, relatively high moving speed. Data packets should be relaid and sent to destination node through the multi-hop routing, if an intermediate link was broken, the path needs to be reestablished or repaired (Blum and Eskandarian, 2007). So, efficient routing protocols are required to function properly (Santos *et al*., 2005). Multi-path routing protocols try to find several paths existing during the discovery phase between sender and receiver. Many applications can use multi-path routing to improve reliability or throughput in traditional routing protocol.

In this study, a novel multi-path routing protocol is presented for vehicular networks based on vehicles movement prediction, estimates the stability of each communication link in the network, and then selects the most stable route composed by the most stable intermediate links from the source till the destination. The concept in AOMDV (*Ad hoc* On-demand Multi-path Distance Vector) (Marina and Das, 2001) is integrated by using the network simulator NS2 and showed its performance improvements.

ROBUSTNESS ANALYSIS OF MULTI-PATH ROUTING PROTOCOL

Multi-path routing protocol is an efficient method to ensure the stability in VANET. When a link breakage occurs, the network connection can be restored by saving backup routes.

Due to the topology is easy to change in VANET, new routes should be found before the contract expires. So, it can reduce broadcast and to increase the path interval through multi-path strategy. There are many multi-path routing protocol in traditional MANET (Mobile *Ad hoc* Network), such as AOMDV (Marina and Das, 2001), AODVM (AODV-based Multi-path Routing Protocol) (Motegi and Horiuchi, 2004), and MSR protocol expands from DSR (Nasipuri *et al*., 2001). These methods can also be used to improve VANET performance. In this section, the robustness of multi-path routing protocol will be investigated analytically.

Consider a path form source node s to destination node D which consisted by k-1 intermediate nodes and k links, assume the life time of a link L_i is mean of random variables X_{li}, i = 1,2,3...k-1, if any route break, the path will be broken.

There is one main route P_l and N-1 backup routes which expressed by $P_1,P_2,...P_N$, the lifetime of P can be express by $X_p = \min \{X_{L1},X_{L2},X_{L3},...,X_{Lk}\}$, which is a Exponential distribution random variable which mean is L/K. if a route P_i is broken, source node try to use another route, the time interval between two route finding can be show as $T = \max \{X_{p1}, X_{p2},...,X_{pk}\}$.

Theorem 1: The probability density function of T is (Ogier *et al*., 1993):

$$\begin{aligned} f_T(t) = {} & \lambda_1 e^{\lambda_1 t}(1-e^{\lambda_2 t})(1-e^{\lambda_3 t})\cdots(1-e^{\lambda_N t}) + \\ & \cdots \lambda_2 e^{\lambda_2 t}(1-e^{\lambda_1 t})(1-e^{\lambda_3 t})\cdots(1-e^{\lambda_N t}) + \cdots \\ & + \lambda_N e^{\lambda_N t}(1-e^{\lambda_1 t})(1-e^{\lambda_2 t})\cdots(1-e^{\lambda_{(N-1)} t}) \end{aligned} \qquad (1)$$

Corresponding Author: Guangsong Yang, School of Information Engineering, Jimei University, Xiamen, 361021, China

where, $\lambda_i = k_i/L$is the lifetime of route i.

Proof: Consider N exponential distribution random variables $X_{p1}, X_{p2},...,X_{pN}$. The probability density function of $X_{pi}(t) = \lambda_i e^{\lambda_i t}$, i = 1,2,3,...,N Due to X_{pi} is independence, the cumulative distribution function of T is (Zaumen and Garcia-Luna-Aceves, 1998):

$$\begin{aligned} F_T(t) &= P[T < t] = P[\max(X_{p1}, X_{p2}, \cdots, X_{pN} \le t] \\ &= P[(X_{p1} \le t) \cap (X_{p2} \le t), \cdots, \cap (X_{pN} \le t)] \\ &= \prod_{i=1}^{N} F_{XPi}(t) \end{aligned} \quad (2)$$

where, $F[X_{pi}(t)] = 1-\lambda_i e^{\lambda_i t}$ is the CDF of random variable X_{pi}, by using differential operation in both side of Eq. 2, fT(t) can be obtained, which is probability density function of T, so it is proofed.

The hop numbers of each link is k_i, i = 1,2,3…,N, where $\lambda_i = k_i/L$ is the lifetime of route i, E(T) is the expectations of T, which can be obtained.

The average routing finding interval of single-path and multi-path can be compared according to the above analysis. In single-path route, the path form source node to destination node is just one, so N = 1.In the multi-path protocol, the in disjoin route from source node to destination node is N. The average interval between two successive routes finding phrase is T, Fig. 1 is the relationship between expectations of T and hop numbers. It can be seen that route finding interval in single-path is littler than it in multi-path, and it increase with the backup routes. With the increase of main path hop numbers, average route finding time decreased, this due to link breakage is easier with increase of hop numbers. With the increase of backup route, average interval increase, show

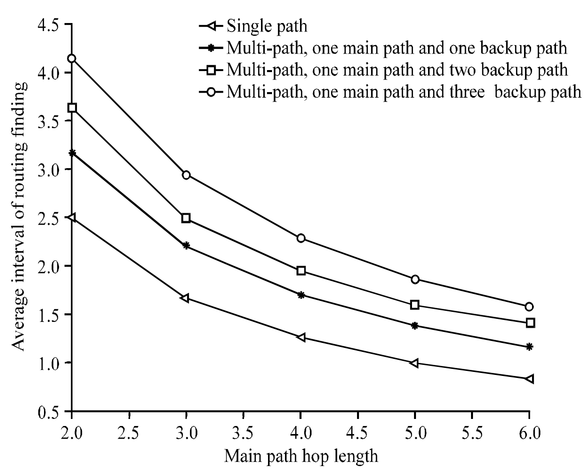

Fig. 1: Relationship between average routes finding interval and main hop length

the network is more stable. When the number of backup paths increased, the routing finding intervals will getting longer, but the control overheads are also increase. So, tradeoff should be done between network robustness and control overhead.

MOBILITY PREDICTION METHOD

In VANET, the nodes always move in high speed, the network topology change frequently, so the node movement should be predicted to choice unbreakable paths. Figure 2 is the idea of movement prediction. Node S move to P with velocity V, the radial distance to destination node D is change from d to d', so, the relative radial velocity is also change form V_r to V'_r.

Assume all node fixed with GPS and know its own location, if node S move to P′ along the arc of a circle with radius d and centered at node D, the distance between P and P′ in different time is $\Delta d = d\text{-}d'$. So, the average velocity form P′-P:

$$\bar{v} = \Delta d/\Delta t \quad (3)$$

where, Δt is time interval from S-P, whether D move outward D or inward D can be predicted, i.e:

$$DM = \begin{cases} \bar{v} > 0 & \text{outward} \\ \bar{v} = 0 & \text{static} \\ \bar{v} < 0 & \text{inward} \end{cases} \quad (4)$$

If node S move to P′′ (dash line circle), it will outward D. If it moves to P, it is tend to be close to D. So, whether the node leave the effectively communications region can be predicted by the metric DM. Because a vehicle which is almost out the communication range should not be selected as a next hop, if the node moves outward, a new route finding can be started and a new path can be created before the link breakage of current path. So, the delay can be reduced by prediction.

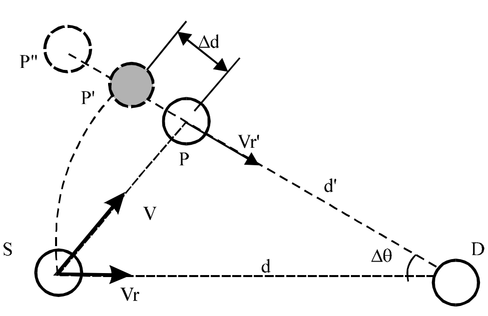

Fig. 2: Mobility prediction model

The efficiently communication region can be estimated before neighbor node leave:

$$v_r T_{min} + d = D_c \tag{5}$$

Where, D_c is efficiently communication distance T_{min} is new route finding interval. When neighbor node satisfy $d \geq D_c - v_r T_{min}$ a route discovery phrase will be start, to find a new backup routes before main path break. The mobility prediction mechanism based on vehicle's movement information, guarantees the selection of the best next hop for data forwarding.

MODIFIED MULTI-PATH ROUTING PROTOCOL

In AOMDV each RREQ, respectively RREP arriving at a node potentially defines an alternate path to the source or destination. Just accepting all such copies will lead to the formation of routing loops. In order to eliminate any possibility of loops the "advertised hop-count" is introduced. The advertised hop-count mechanism establishes multiple loop free paths at every node. These paths still need to be disjoint.

One of the main shortcomings of AOMDV is that the only characteristic considered when choosing a path is the number of hops. Path stability is completely ignored.

Thus, selected paths tend to have a small number of long hops meaning that nodes are already close to the maximum possible communication distance apart, potentially resulting in frequent link disconnections.

In this section, a modified AMODV protocol named Moving Prediction based AMODV (MP- AMODV) will be proposed, the main idea is limited the numbers of backup path to decrease the routing overhead, introduce the link breakage prediction mechanism, to improve the stability of multi-path routing protocol.

A DM (Direction metric) field will be added in RREQ packet according (3) and (4), which can predict the link breakage, the work process is below:

Route discovery: When the source node needs to communicate, first check whether there is an existing path in the routing table, otherwise initiated the process of route request and broadcast RREQ message. When a node received the RREQ, first verify whether its own is the destination node, and whether other destination node received this message, if not, relay this RREQ.

If satisfy the condition, it will store the first received RREQ packet and initiated a timer. AODV uses a timer-based technique to remove stale routes promptly. Each routing entry is associated with a soft state timer called route expiration timeout. This timer is refreshed whenever a route is used. Periodically, newly expired routes are invalidated.

When a node received the copy of other RREQ, Check whether it can provide new disjoint path by look up the first hop field of RREQ. If so, the disjoint path will be stored on this node, otherwise it will be discarded.

When the timer expires, all the RREQ will be discarded. If there is no valid path to reach the destination node, the relay node will forward the first RREQ packet. If DM>0,stop forward the message, so link breakage can be avoid by compute the DM according to Eq. 3 and 4.

Route reply phrase: When destination node received the first arrived RREQ, it will create a RREP and unicast it to source node. In order avoid the RREP storm, the numbers of RREP should be control by compared the value of, select the backup routes with bigger and relay the RREP along the return path.

Data transmission phrase: When the multi path is setup, the data begin to send data by using main path, backup routes is ready to be used as soon as the main path is broken. After all paths are invalid, new route discovery phase is re-initiated.

Routes maintenance: Route maintenance is done using route error (RERR) packets. When a link failure is detected (by a link layer feedback, for example), routes to destinations that become unreachable are invalidated. In mobile environments, it is necessary to find efficient ways of addressing path failure. Route maintenance in MP-AOMDV takes advantage of a handoff strategy using mobility prediction. When the predicted link tend to broken, the algorithm discard the path and ready to change to good path.

When a link is broken, the node broadcast the RRER to neighbor nodes, after receiving this message, the relay nodes will delete the correspond entry in routing table.

RESULTS AND DISCUSSION

MP-AOMDV performance are evaluated using ns-2 simulations. The main objective is to evaluate effectiveness of proposed protocol.

Manhattan and Freeway model (Bai *et al*., 2004) are used to simulate the VANET scenario in city and high way, respectively. The city scenario is 1000×1000 m area withthree cross streets and three vertical streets, including 12 two-way lane, there are 50 vehicles moving on it, maximum node speed was increased from 5-40 m sec^{-1}.

High way scenario is two-way four-lane 5000 m length highway, with 50 vehicles moving on it,Maximum node speed was increased from 10-50 m sec^{-1}. MAC protocol is 802.11 with 2 Mb sec^{-1} channel bandwidth,

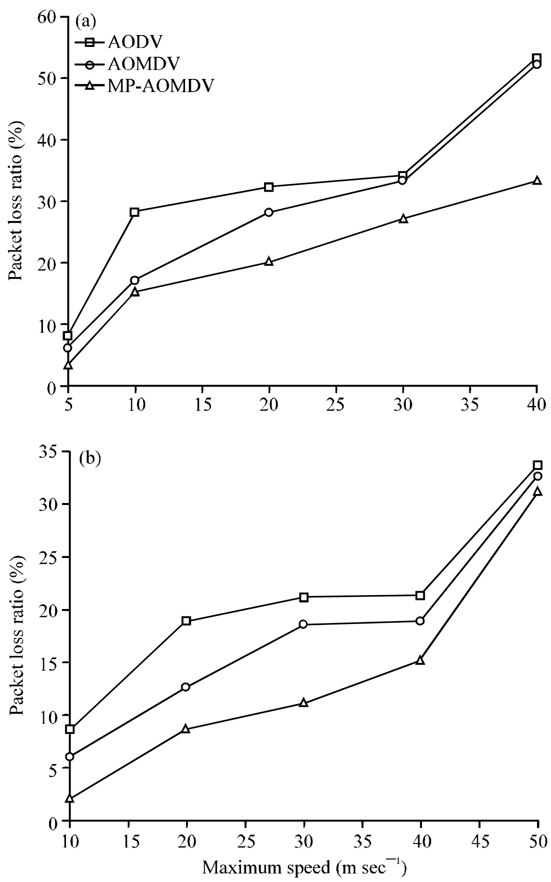

Fig. 3(a-b): Pack loss ratio in different scenario, (a) City scenario (b) High way scenario

100 sec running time, 512 bytes CBR sources were fixed at 5 packets sec^{-1}.

Figure 3 show the packet loss obtained for each routing protocol as function of vehicle,s maximum speed in different scenarios. As shown in both city scenario in Fig. 3a and high way scenario in Fig. 3b, higher the vehicles' maximum speeds, higher the packet loss, but MP-AOMDV had better delay performance when compared to AODV and AOMDV. This due to stable backup paths selection in MP-AOMDV can increase the probability that link failures will be avoided during the whole communication. So, it helps as well in minimizing the risk of broken links and in reducing data loss.

CONCLUSION

In mobile environments, it is necessary to find efficient ways of addressing path failure. A routing metric is proposed, which utilizes the mobility prediction metric by measuring the relative velocity to select the stable links which is an extending of AOMDV. During the route discovery, difference of velocity of the nodes can be predicted. In route maintenance, the proposed approach maximum avoids to link failures and maintain the stable paths. The simulation results show that the proposed protocol can minimize disconnections, reduce transmission latency and packet drop rate. In the future work, the dedicated MAC and routing optimization for VANET will be more investigated.

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