Silent Alarm: Path Optimization Route Lifetime for VANET Multi-Hop Routing Protocol

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Abstract – Raising vehicle crime is one of major concerns for public opinion nowadays. One proposed solution to this issue is via development of Vehicular ad hoc networks (VANET) that enable vehicles to exchange information within a network without the need of installing any infrastructure along the roadside. The risk of the car and motorcycle theft could be mitigated by tracking theft vehicle with installation of conventional alarm and Geographical Position System (GPS) in each vehicle. In this paper, issue is focused of the need for detailed planning to ensure optimal design and deployment of the VANET. Research problem been formulated when there is multiple choice of route, to choose the route that has optimal route lifetime within two directions node movements with minimum latency will be achieved within node transmission range. Some enhancements also need to be done to the algorithm to solve the issue. Initial performance optimization evaluation will be used Matlab simulation.

I. INTRODUCTION

Nowadays, in developing countries, the rising of many kinds of crime is one of the major concerns for public opinion. Indeed, in Malaysia, based on news report, it was estimated that amount of serious crimes have increased by 13.36 per cent and also gang robbery by more than 159 percent in the year 2007 According to the news report, several efforts have to be taken by the police with the goal to curb the rising crime rates. This including installing more closed-circuit television camera (CCTV) in buildings and common areas, also by building more police stations near shophouses and in housing estates. Nevertheless, the result is still unconvinced.

At this point, we proposed a new way of solving this issue via development of silent alarm system in VANET (Vehicular Ad Hoc Network). The goal is to reduce particularly the car and motorcycle theft crime that arise. The risk of the car and motorcycle theft could be mitigated by the installation of conventional alarms and Geographical Position System (GPS) in the vehicle. Specifically, the system would use VANET type of network, GPS to trace the current theft vehicle location and speed. To be considered, designing this VANET system for theft deterrent system require limited packet delay transmission. To guarantees this issue, its only depends on medium access activities (collision and back offs), transport activities (congestions and flow control) and routing activities (queuing, broadcasting and forwarding).

For this research, the proposed system is VANET access points (AP) will be installed at specific locations along roads and in crime-prone areas. Each car or motorcycle is to be fitted with a low-cost transmitter, and each is able to act as a node within the VANET. Throughout this paper, we consider the vehicle as a node in VANET. When a vehicle break-in happens, the vehicle concerned will broadcast a ‘silent’ alarm contains alarm message to be received by the nearest AP directly or via an ad hoc network chain of vehicle. The alarm message may also be relayed to cell phone networks. The alarm message will eventually be received the police. For legal purpose, the police would be able to track path taken (node visited) by the message. The alarm message contains a unique id for each registered car to make other vehicles or polices can recognize the theft vehicle.

In this model, the network is in dense traffic scenario on highway. The highway has two lanes consist of two difference directions. Consider this kind of scenario; multiple possible choices existed for selecting an optimal path. The research problems been formulated where there are multiple choices of routes, and to select the optimal route lifetime within two directions node movement. The optimal path will be selected when minimum delay can be achieved. The silent alarm that contain emergency packet will notify to the access paint about being broke in and the access point will broadcast the information to all nodes within its transmission range. So, the silent alarm should be sent to access point as soon as possible where it cannot tolerate with the delay. The research problem formulates when there are multiple choices of routes, to choose the route that has optimal route lifetime within two directions node movements, forward and backward by comparing delay value of each relay node. Figure below represents the scenario in VANET for selecting path.

Figure 1: Preliminary VANET System Model and node forwarding selection
From figure 1, S develops silent alarm to transmit to D. It is consists of one access point that installed at one side of highway. One node actually becomes a victim of being theft. It attempt to send silent alarm to access point but not directly but using relay node. However, there are three choices of route path that possible to use by S. Since there are multiple choices of path in routing activities, the difficulties of the problem is to choose the path. However, this can be solved by discover how to achieve objective to obtain an optimal path for sending ‘silent alarm’ from sender (Vehicle) to destination (Access Point) with minimum delay and how to predict route lifetime within two directions in highway.

The objective of this research is to find an optimal path to transmit silent alarm from source to destination with minimum delay based on prediction of optimal route lifetime. However, the detail metrics for routing evaluation will be described in next section of this research paper.

II. LITERATURE SURVEY

There are several proposed strategies and contributions creating and enhancing routing algorithms that aims to achieve path optimization. An author in [6] had proposed an idea on how to get and optimal path with optimal speed and distance between nodes so that maximum route lifetime will be attained. However, the author only considers one side of moving node on highway.

The authors [7] proposed Movement Prediction-Based Routing (MOPR) concepts for VANET. According to authors, this routing concepts can improves routing process by selecting the most stable route in term of life time with respect to the movement of vehicles. Authors proposed an algorithm to solve this issue to find stable route by predicts link lifetime by predicts future positions of vehicle that occupy in each routing path based on their positions, speed and directions. Thus, the optimal route selection for data transmission is based on the MOPR algorithm to predicts if an intermediate routing node is likely to cause rupture link during transmission time or not. The stable node in this paper is referring to node that should have same direction and speed to destination node.

Authors also make some improvement on the algorithm on that the MOPR in [14]. The improvement made on decreasing size of RREQ packet transmitted between nodes. For the enhancement, it called Intelligence where nodes able to know earlier about the position and movement information (current distance) of neighbour node when receiving the new RREQ packet. Even though the algorithm able to predict link lifetime, but it not consider the delay that may existed.

Authors in [8] formulate the problem of optimal next-hop selection in a route between two vehicles on highway. The authors also try to find the optimal number of hops in one link. For their research, the optimal selection of next-hop is the maximum route lifetime based on vehicle speed and inter-node distance. Extend of the research, the authors proposed a scenario where two vehicles are moving on the highway. To get the optimal path, the author proposed to solve the problem formulation to find the optimal inter-node distance first. Then, having solved the problem, authors proposed to determine the expected link lifetime. However, this research only focuses for one direction only. They ignore the scenario of opposite direction of vehicle movement. However, at the end of research paper, authors not able to get the optimal number of hop for each link.

Authors in [11] proposed an algorithm that focusing on delay bounded in VANET. According to the authors, delay is high for the application which requires propagation of information hop-by-hop to a single destination point or area. Refer to their proposed scenario, the application applied on the vehicle which equipped with sensor to detect accident and traffic. Here, it has many types of messages with different priority and delay threshold until they are delivered. For their paper, the proposed algorithm is kind of traffic-informed and it adapts its behavior based on traffic density and average speed to minimize delay and utilization of wireless medium. According to their proposed algorithm called D-Greedy, it assumes the best path to the Access Point (AP) is the shortest path. However, if there is multiple AP, the algorithm with choosing the closest one. The detail on how it works is described in [11].

Authors in [12] also done a study on how to broadcast packet efficiently in VANET for optimize the design for VANET. According to the authors, DSR and AODV are not appropriate to be applied in VANET for most vehicular broadcast Authors proposed a design called Distributed Vehicular Broadcast (DV-CAST) Protocol for routing solution to cope with three extreme situations such as: i) Dense Traffic Regime (sometime called broadcast storm problem), ii) Sparse Traffic Regime (case where not many vehicle on the road) and iii) Regular Traffic Regime. Here, three actions that node should follow for efficiently broadcast packets such as Well-Connected Neighborhood, Sparsely-Connected Neighborhood and Totally Disconnected Neighborhood. This protocol is based on local information established by each node (vehicle) via periodic sending beacon message. The result of this protocol is fully distributed to nodes in the network. However, we have to consider the factor that could make the protocol fails such uncertainty of VANET topology as stated by the authors.

III. PROPOSED SOLUTION

A. Model and Preliminary

Generally, VANET is represented as a graph $G(V, E)$, where vehicles represent a set of vertices $V$, and a set of edges $E$ represents direct communication links. This vanet system model will follow the simple communication model that is used in [9] where it set a communication link with $e_{i,j}=(v_i, v_j)$ will exists if and only if the Euclidean distance between vehicles $v_i$ and $v_j$ is less than or equal to the shortest transmission range between them, i.e,

$$E = \left\{(v_i, v_j) \in V^2 | d(v_i, v_j) \leq \min(r_i, r_j)\right\}$$  \hspace{1cm} (1)

Where $v_i, r_i$ are the position and transmission range of the node $v_i$, respectively. As according to the authors in [10], the equation (1) implies that the graph $G(V, E)$ is a undirected graph. For this proposed system, the problem may arise when there are multiple selecting paths. Refer to
Initial Condition and Assumption: Assumption need to be set to focus on the research scope. For this model of research, let us assume some initial conditions before detailing the methods used.

1) A node consist in this network may be and intermediately which is vehicle, a receiver which may be vehicle or access point, initial node which is an emergency vehicle (designated under name of source where for vehicle that been theft and generate emergency message and send silent alarm), or destination which is access point.

2) Scenario takes place is on straight highway with four lanes will be used for this research where two lanes for forward and two lanes for backward (two links that moving opposite with each other two links).

3) Every vehicle that installed with VANET is equipped with GPS receiver.

4) One Access Point was installed at one side of the highway will be a destination.

5) Assume that traffic condition is free-flow traffic.

6) For the evaluation section, the intermediate relay nodes are between 1-6 nodes as proved by other researchers that this value is the most efficient for VANET.

Figure below detail describes about difficulty of the problem that may arise in selecting multiple paths.

At this point, refer to figure 2 above, we assume that nodes in proposed VANET system have there different paths where each path has different scenario. At this point, the victim node should select the optimal path by predicting the route lifetime and delay to forward the emergency silent alarm to the respective relay node either via P1, P2 or P3. The selection requirement for this research is based on the route lifetime and delay between nodes. From figure 2, Path 1: P1 Node is out of Transmission Range value (Direction 2), Path 2: P2 Node at maximum Transmission Range value (Direction 1) and Path 3: P3 Node within Transmission Range value (Direction 1). Here our contribution is take place.

The methods for calculating the metrics and predicting the route lifetime is describe in the next part. Note that different directions are using different equation for prediction route lifetime. DSRC/802.11p communications technologies can support inter vehicle communication with maximum transmission range of 1000m [1]. Table 2 and table 3 below is one of our contributions presenting the concrete explanation on how the silent alarm works and how the system reacts in selecting the optimal path. The explanation is exposed as pseudo code.

**Table 2**

<table>
<thead>
<tr>
<th>Source Node and Intermediate Node (Predict Route Delay)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predict and Discover Its Delay,</td>
</tr>
<tr>
<td>If its Delay &lt; Max-Delay</td>
</tr>
<tr>
<td>Replace Max-Delay with its Delay</td>
</tr>
<tr>
<td>If Sequence Number exists</td>
</tr>
<tr>
<td>Compare Max-Delay of current RREQ with Max-Delay of existing one.</td>
</tr>
<tr>
<td>If new Max-Delay &gt;= old Min-Lifetime</td>
</tr>
<tr>
<td>Discard new RREQ</td>
</tr>
<tr>
<td>If new Max-Delay &lt;= old Min-Lifetime</td>
</tr>
<tr>
<td>Replace old Max-Delay with new Max-Delay</td>
</tr>
<tr>
<td>Forward new RREQ</td>
</tr>
<tr>
<td>If Sequence Number does not exist</td>
</tr>
<tr>
<td>Save this Max-Delay</td>
</tr>
<tr>
<td>Forward RREQ</td>
</tr>
<tr>
<td>Broadcast Beacon Message</td>
</tr>
<tr>
<td>If next hop does not exists</td>
</tr>
<tr>
<td>Save Beacon Message in cache until</td>
</tr>
<tr>
<td>discover next hop or AP</td>
</tr>
</tbody>
</table>

**Table 3**

<table>
<thead>
<tr>
<th>Source Node and Intermediate Node (Predict Route Lifetime)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predict and Discover Its Route Lifetime</td>
</tr>
<tr>
<td>If its Lifetime &gt; Min-Lifetime</td>
</tr>
<tr>
<td>Replace Min-Lifetime with its Lifetime</td>
</tr>
<tr>
<td>If Sequence Number exists</td>
</tr>
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<td>Forward new RREQ</td>
</tr>
<tr>
<td>If Sequence Number does not exist</td>
</tr>
<tr>
<td>Save this Min-Lifetime</td>
</tr>
<tr>
<td>Forward RREQ</td>
</tr>
</tbody>
</table>

**B. Related Protocol**

Below describe about how to predict the route lifetime to select optimal path. Then, follows by DSRC communication technologies and how it can exploit in VANET using others prediction equation. This is become one of our contribution to this paper.

1) Prediction to Obtain Route Lifetime: To obtain route lifetime, RREQ, RREP and RERR should be used. RREQ is Route Request message generated during the route discovery process, RERR is Route Error packet caused by
abrupt link failures and RREP packet from the gateway is used to gather information to predict the lifetime of the route.

Let assume that the communication range of the Wireless LAN technology used be R. According to authors in [9], if the absolute distance between two nodes i and j is denoted by |dij|, and their corresponding velocities given by vi and vj respectively, the lifetime of a link between i and j is predicted as,

\[
\text{Lifetime}_{\text{link}} = \frac{R - |d_{ij}|}{|v_i - v_j|}.
\]  

(2)

Since a route comprises of one or more links, the route lifetime is the minimum of all its link lifetimes. i.e.

\[
\text{Lifetime}_{\text{route}} = \min \{\text{Lifetime}_{\text{link}} \}.
\]  

(3)

The link lifetime equation is altered slightly in the algorithm to predict link lifetimes when routes pass through vehicles moving in opposite directions as well. Since the road carrying oncoming traffic can be quite far apart from the road carrying forward traffic, the algorithm now takes into account this separation distance, w. As before, we ignore the width of the road in this calculation for simplicity. Thus, if two end vehicles of a link are moving in opposite directions,

\[
\text{Lifetime}_{\text{link}} = \frac{\sqrt{R^2 - w^2} + s\sqrt{d_{ij}^2 - w^2}}{v_i + v_j}
\]  

(4)

where s = 1 when the two vehicles are moving towards each other, and s = -1 when they are moving away from each other. This lifetime gives the expected time based on current speeds for two vehicles at a distance |dij| from each other before they move apart by more than the communication range R. Note that |dij| always for a constant separation distance between a pair of straight roads.

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Distance between two nodes is used as the primary indicator of whether two nodes are able to communicate with each other. When two nodes move apart by a distance greater than R, their link is assumed to be broken. This model can be easily adapted to provide more sophisticated predictions based on radio characteristics, signal strength, direction of motion among others, and applied to other wireless ad hoc network settings as well. Similar to using routes through oncoming vehicles, vehicles moving in other directions or other static Wireless LAN installations can be considered too when faced with a lack of vehicle density resulting in inadequate connectivity. The protocol and prediction algorithm can be modified as above for these scenarios too.

2) Dedicated Short Range Communication (DSRC): Second phase, we should identify what the aspects that need to investigate for designing vehicular ad hoc network so that we can proposed the proper protocol and decide which algorithm to be used to get an optimal design and deployment of VANET.

In order to provide latency minimization, message prioritization, and elements of security (authorization and anonymity), FCC has allocated 75 MHz of spectrum in the 5.9 GHz band for Dedicated Short Range Communications (DSRC or 802.11p) for VANET communications. The DSRC spectrum is allocated for vehicle-to-vehicle and infrastructure-to-vehicle communication. In DSRC, the 5.9 GHz (5.850-5.925) band is divided into seven 10 MHz channels, with explicit allocation of one control channel and six service channels to accommodate diversity of applications envisioned for VANET. For our proposed VANET system, seven channels of 10 MHz each, one control channel (monitored by all vehicles on regular basis) and six service channels. The emergency alarm will be sent in the control channel and all beacon messages will be sent in service channel. Since there are up to six services channels to transmit beacon messages from all nodes in the network, delay can be reduced.

IV. TESTING ENVIRONMENT

For the evaluation of this research, we had proposed some metrics and parameters and possibly the simulation will be used. Following is the possible optimization parameters that should be considered to find the optimal path for this research model.

1) optimization over inter-node distance within transmission range
2) optimization over route lifetime (failure)
3) optimization over velocity of the intermediate relay node

For this model, we already assumed that every vehicle was equipped with GPS receiver and also assumed that number of relay node in the network is known in advanced. The details for setup as described in previous section. Referred to the optimization parameters above, the goal is to obtain the optimal path to forward the emergency packet.
(silent alarm) with minimum latency within minimal route failure for each node. To calculate and obtain route failure, signal strength as route selection strategy for each node within transmission range should be considered. By obtain this value, an optimal path selection as routing strategy for silent alarm in VANET will be reliable. The sensitivity of this optimization proposed will be evaluated under various related metrics.

A. Simulation Setup Value

Generally, VANET characteristic is influenced by the characteristic of the traffic flow. Refer to table below, it shows a proposed simulation setup value for testing the proposed equation for the system.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermediate Relay Node (M)</td>
<td>Min = 1, Max = 6</td>
</tr>
<tr>
<td>Transmission Range (R)</td>
<td>200 m</td>
</tr>
<tr>
<td>Highway Length</td>
<td>2000 m</td>
</tr>
<tr>
<td>Number of Link</td>
<td>4 (2 Directions)</td>
</tr>
<tr>
<td>Velocity</td>
<td>Max = 70 mph (31.3 m/s)</td>
</tr>
<tr>
<td></td>
<td>Min = 40 mph (17.8 m/s)</td>
</tr>
<tr>
<td>Data Rate</td>
<td>1 Packet Per Second</td>
</tr>
</tbody>
</table>

VANET performance also change in different traffic scenario and network mobility affected by vehicle density that changing based on average vehicle speed. For this scenario, we consider the parameter setup for this research should be based on traffic condition and as proposed by author in [1]. However, here we will set a parameter using common static transmission range.

B. Simulation Parameter

Simulation parameter for the proposed system is being decided and these are the parameters should be used during evaluation part. The reasons behind chosen all these parameters are to include in calculation to find the optimal path selection in VANET multi-hop environment. The simulation parameters chosen:

1) route lifetime \( (\text{Lifetimelink}) \)
2) vehicle velocity \( (v) = \text{speed (s)} \) and distance between node\( (d) \)
3) communication transmission range \( (R) \)
4) number of link \( (L) \)
5) separation distance between node in opposite directions \( (w) \)
6) density - mobility moving speed (as proposed by Kumar is 23m/s)

C. Performance Metrics

The output of this research is based on the comparison of these performance metrics below:

1) Average latency (Delay Per Time)
2) Delivery delay (why?)
3) Node lifetime
4) Signal Strength

V. Evaluation

There are two approaches to evaluate routing protocols and latency in VANET: One is by using simulation or by performing experiments on real hardware. For analysis and result, to propose an optimal design and deployment of VANET, the evaluation based on its enhancement of performance and by comparing the value of performance from others research work and also based on standard value of BER (Bit Error Rate) in wireless transmission. From this result, we will conclude which proposed protocol is better in developing VANET for real. In this phase, some enhancement to get the most suitable routing approach and algorithm to achieve the optimal design and deployment of VANET system is needed.

Logical Evaluation: MATLAB will be used in this phase for evaluation of proposed strategy and technique designing VANET. From the proposed performance metrics evaluation, the goal of this research is to find the best path that minimize the latency and BER value of a route between any pair of nodes or access point that can not communicate directly. Thus, it requires relaying by intermediate nodes with optimal number of node. As previous problem formulation stated in introduction section, this research is about to forward the silent alarm to optimal node selection so that we can minimize the delay. The other problem that we address is to identify the optimal number of node in network chain between the optimal distance and minimal latency in VANET communication transmission. The criteria included for this purpose was described in precious section.

As for further enhancement, there will be another comparison between distance and BER will be evaluated based on optimal number of node proposed in one VANET. The evaluation will be based on the graph calculated in MATLAB to get the best node with optimal route lifetime and minimal latency with optimal number of node (standard is between 1 to 6 nodes).

VI. Conclusion

Generally, VANET lifetime is not always established. Many possibilities that can lead to network disconnected such as connection between nodes disconnect because of the distance. To achieve the goal of this research is quite challenging since the node in the VANET is not static and always moving with unpredicted speed. Since VANET is one of the emerging research nowadays and because of its challenging class of MANET (Mobile Ad Hoc Network). As authors in [13] said, this VANET is self-organizing communication, distributed nodes within network and thus characterized in very high speed of node and limited degree of node movement. However, based on the literature survey done during study phase and studied about VANET routing protocols, the goal and expected output from testing environment will be achieved where we can predict the duration of the connection in the network by predicting the route lifetime between node. From this stage, silent alarm can be forwarded to the destination successful by choosing the optimal route lifetime of node especially in two different directions. The proposed idea of optimization route lifetime
for the formulated problem is demonstrated as pseudo code as shown in section III.

Our contribution of this research is to propose a solution of route lifetime prediction in two directions by comparing their velocities with the delay. Another contribution to this paper is we proposed on how to exploit the seven channels standard and characteristic of DSRC allocated for vehicle communication for better services in VANET. By applying equation (1-4) as stated in section III into DSRC channel, we expect the result will be achieved in promising performance.

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