Abstract—Heuristic Mobility-Aware OLSR Protocol was designed for VANETs in which nodes rapidly changed in speed and direction. This protocol will be collecting information of adjacent nodes and interpreting as a routing cost. The sum of the routing cost of all nodes along a candidate route is to be a routing metric. The route with the minimum cost index is selected based on the key that the lower the routing cost the robust the route is. The routing metrics for measuring the routing cost is incorporated with the transmission capability, the reliability and congestion around the link including the data rate, queuing delay, link quality, and MAC overhead. Our simulation results proved that the proposed routing protocol attains the stable link and throughput.

Keywords—Heuristic Mobility-Routing OLSR Protocol; VANET; Routing Cost; MAC overhead; Throughput, Packet.

I. INTRODUCTION

Inter-Vehicular Communications (IVC) or Vehicle-Vehicle Communications (V2V) and Road-Vehicle communications (RVC) made for traffic management and road safety reasons. Both IVC and RVC emerge from the mobile ad-hoc networks (MANETs) name for the vehicular ad-hoc network (VANET) [1]. VANET is the special case of MANETs that are vehicle to be mobile nodes. Recent years the importance of VANET has been recognized by many organizations such as car manufactures, the government transportation bureau, etc.

Applications for VANET include the traffic control by broadcast information about the traffic situation such as the traffic and accidents, or the road condition such as road-wet condition these can be improve drivers’ vision caused by the hazardous condition of road, traffic congestion or a sudden stop. Figure 1 shows the example of V2V communication.

Recently, The U.S. Federal Communications Commission (FCC) allocated 75 MHz for Dedicated Short Range Communications (DSRC) spectrum at 5.9 GHz to be used exclusively for V2V and V2R communications [2]. The DSRC is divided into seven 10 MHz wide channels as shown in Figure 2. The channel 178 is the restricted channel used for control channel, the two channels at the edge reserved for advanced and the rest is used for both safety and non-safety applications.

The study of VANET involves many key technologies such as Global Positioning System (GPS) or Differential Global Positioning System (DGPS) to improve accuracy of it location, Geographic Information System (GIS) to specify its location to the map. Moreover the importance of routing protocol is the key to establish the suitable route from the source to the destination for data access between vehicles.

Many Researches in routing protocol in VANET try to improve the link expire time before finishing transmit all data such as [3] [4] and [5].

Figure 1. Example of the inter-vehicle communication to improve drivers’ vision.

Figure 2. DSRC Channel assignment in North America
The paper studied the feasibility to adopt the new routing protocols to improve the disconnection from the mobility of nodes by using heuristic means to reduce the calculation time for complicated mathematics models.

II. RELATED WORKS

Link State Routing Protocol uses available information about the connectivity and the topology of neighbor nodes. Moreover, this protocol increases the chances to generate a route that meet a specified case of constraint. To improve the Link State Routing Protocol, in [6], the authors proposed the Optimum Link State Routing (OLSR). OLSR is an optimization of the classical link state routing protocol designed for mobile wireless networks [7] and standardized by IETF in RFC 3626 [6]. Every node periodically broadcasts Hello messages that contain its link and neighbor list.

The link state information is only generated by the multi-point relays (MPRs) and disseminated throughout the network by Topology Control (TC) message. Each node has an overview of all the network information, and maintain its routing table to every node by calculate the shortest path in term of the minimum hops; when a node designated by “SRC” wants to communicate to the destination node designated by “DST” and send route request to the DST, the DST will send back the RREP via the selected nodes contained in the message.

In [8] and [9], they proposed the enhancement of OLSR by putting QoS in to Link Message Size and Htime fields of the Hello message called QQLSR. The QQLSR use multiple details as the input function and use heuristic means to solve problems.

In [10] proposed the heuristic Fuzzy path selection to find the route from the source to the destination node but the mobility of nodes is not considered, we use the heuristic means and optimized the some parameters of the input functions to make the protocol suitable for VANET with different mobility.

III. ROUTING PROTOCOL

A. Network Model

The network model is in under assumption as the following:
- Every node has unique id, and node synchronization is available.
- Every node known its geographical coordinate and speed as well as adjacent nodes.
- All nodes have the same capabilities; there is no central base station.
- All nodes have the same routing protocol.

B. Input Functions

Consider Figure 3 that nodes N1, N2 and N3 have speed $S_i$ and nodes N4 and N5 have speed $S_j$. We have two input functions for route calculation as follow.

C. Establishing Route

Providing that all vehicles are represented by mobile node, the network topology is shown in Figure 4. When the source node “SRC” wants to communicate to the destination node “DST”, and every node use MAC protocol to control the congestion of media.

For route discovery of OLSR, HELLO messages periodically broadcasts and collects 2-hop neighborhood information and performs a distributed election of a set of multiple relays (MPRs). Hence, this mechanism can be easily extended to carry the weight information as well. In RFC3626, the structure of an HELLO message is given. For carrying the cost, the standard Hello message was modified in Htime field and Willingness field to include the cost of the neighbor.

Both Cost and Nb_Cost fields are of 8 bits length. Cost field holds the cost information of the originating node. The Nb_Cost field holds the advertised link’s associated neighbor node’s cost information. In a single HELLO message, there is only one Cost field, but there might be multiple Nb_Cost fields depending on the number of the links advertised. Using this extended HELLO message structure; every node will be able to collect the cost information of all the nodes in its 2-hop neighborhood via the routing layer without requiring the MAC layer to exchange any further control messages. Extended Hello Message is show in figure 5.
For route request of OLSR, the source (SRC) sends a route request (RREQ) to the destination. When an intermediated node receives the RREQ packet, it first searches its routing table which can be divided into two scenarios:

Scenario I: if the destination (DST) is in the routing table, the MPR node will send RREQ to the DST via the MPR(s) in to the DST

Scenario II: if the DST is not in the routing table, the MPR node will send RREQ broadcast until the RREQ to be sent to the DST or time out.

From figure 4, the 1st hops node and 2nd hop nodes are in the routing table of node A, B, C, D and E. Examples of routing table of node SRC and node A shown in the Figure 6.

For route reply in OLSR, when the DST receives the RREQ before the packet timeout, DST automatically calculates the routing cost. For example, the costs - from the SRC via A, E to DST - are $C_{\text{SRC-A}}$, $C_{\text{A-E}}$, and $C_{\text{E-DST}}$, respectively. The routing cost from the SRC to the DST is shown in (1).

$$C_{\text{SRC-DST}} = C_{\text{SRC-A}} + C_{\text{A-E}} + C_{\text{E-DST}}$$

Generally, the routing cost can be express as (2) and the selected route from candidate routes represent in (3).

$$C = \min \left( C_1, \ldots, C_n \right)$$

For route update in OLSR, when the DST receives the RREQ before the packet timeout and the packet contains new information, DST will calculate the routing cost. If the new cost is lower than the cost in the routing table, the DST will update the routing table. Every node in the networks proceeds in the same ways.

### A. The MAC Delay Estimation

Estimating the MAC delay affected the wireless scenario; the packet arrival rate and the service time must be considered. Since both parameters are random variables, they can be described in statistical term and thus have the probability distribution associated with them. The message arrival rate is under assumption that is based on a discrete distribution of events and has a large number of independent arrival packets. The common model use for the arrival process is the Poisson statistic \([11][12]\). The $k$ packets arriving as Poisson distribution has the probability $P_n(t)$ during a time interval length $t$ is given by

$$P_k(t) = \frac{(\lambda t)^k}{k!} e^{-\lambda t}$$

Where $\lambda$ is the mean arrival rate.

$$k = 0, 1, 2, \ldots, \infty.$$ 

Hence, no packet arrive during the time interval $t$ is

$$P_0(t) = e^{-\lambda t}$$

In MAC protocol, M/G/1 queuing model is used for modeling the protocol \([13][14]\). The throughput of the system denoted by $\gamma$ is given by in term of the blocking probabilities $P_B$

$$\gamma = \lambda \left( 1 - P_B \right)$$

Define:

$$\rho = \frac{\lambda}{\mu}$$

as the offered load of the system. The length of data frame from node $i$ as $E[P]$, and $C$ is the link capacity. Can be found as

$$\mu_i = \frac{C}{E[P] + H}$$

where $H$ is the overhead of RTS/CTS and ACK control frame. Thus can be estimated by

$$\lambda = \frac{1}{E[w] T}$$

where $E[w]$ is the expected value of the contention window $w$. The contention window $w$ is random variable uniformly distributed between $w_{\text{min}}$ and $w_{\text{max}}$ according to the CSMA/CA protocol. In general, $w$ is uniformly polled from $[w_{\text{min}}, w_{\text{max}}]$; thus the expected value is $E[w] = \frac{w_{\text{min}} + w_{\text{max}}}{2}$. Substituting $E[w]$ into (9), the arrival rate can be rewrite as

$$\lambda = \frac{2}{(w_{\text{min}} + w_{\text{max}}) T}$$

Substituting (8) and (10) into (6), $\rho$ can be computed as
In this system the expected value $E[s]$ has increased linearly and randomness, ‘disarray’, leads to an increased waiting time and queue length. The queue length is the extra factor. In case of the exponential distribution [13], $V[S] = E[S]^2$ leads to $C^2_v = 1$.

Hence,

$$E[N] = \frac{\rho}{1 - \rho} \quad (12)$$

$$E[T] = \frac{1}{1 - \rho} E[S] \quad (13)$$

The transfer delay suffered with the collision at any node denoted by $E[B]_{(i,j)}$.

In the system each node alternated between busy period and idle period. During busy period, the node executes the RTS/CTS, transmits data, and receives ACK. If that node has multiple frames to send, that node will send the same protocol more than once during the busy period. The average time that medium is send during the busy period is denoted by $T_S$ and shown in (14)

$$T_s = \text{DIFS} + \text{RTS} + 3 \text{ SIFS} + \text{CTS} + \text{H} + E[P] + \text{ACK} + 4\delta \quad (14)$$

Where $E[P]$ is the average length of frame, $H$ is the MAC, and $\delta$ is the propagation delay that approximately by 1μs.

The average time of the medium is sensed busy by each station when a collision occurs during RTS/CTS can be denoted by $T_C$.

$$T_c = \text{DIFS} + \text{SIFS} + \text{RTS} + \text{CTS} \quad (15)$$

Consider an ad-hoc node begin transmission, it may collide with other mobile nodes. The probability of the transmission is collided denoted by $c$ and the probability of successful is denoted by 1−c. The number of back-off window can be described by

$$w = (1-c)\frac{w}{2} + c(1-c)\frac{2w}{2} + \ldots + c^M(1-c)\frac{2^Mw}{2} + c^{M+1}\frac{2^Mw}{2} \quad (16)$$

From (16) can simplify by

$$w = \frac{1 - c - c(2c)^M}{1 - 2c} \frac{2^Mw}{2} \quad (17)$$

The collision probability that a node is suffered from N adjacent nodes can be approximated as $1 - \left(1 - \frac{1}{N}ight)^{-1}$ and can be simplified as

$$c = 1 - \left(1 - b_2 \frac{1 - 2c}{1 - c(2c)^M} \frac{2^M}{w} \right)^{N-1} \quad (18)$$

Solving $c$ can be accomplished by iteration means or the Monte Carlo approximation and the arrival probability is denoted by $b_0$.

In the Service Time Distribution, providing that $m$ is the maximum the back-off state and can have value larger than $M$. Determine the maximum $m$ can be at most $M+1$. The approximation of $w_i$, where $w_i$ is uniformly distribution, is

$$w_i \equiv \begin{cases} U(0,2^Mw-1), & 0 \leq i \leq M \\ U(0,2^{M}w-1), & i > M \end{cases} \quad (19)$$

The aggregated approximation for the back-off window size depended on the probability $c$ is shown below

$$w_n = \sum_{i=0}^{m} c^i w_i \quad (20)$$

The service time for an arbitrary frame is determined based on the MAC is

$$E[B] = T_s + w_n T_c \quad (21)$$

### B. Heuristic Routing Cost

**CASE I: Routing Cost of Neighbor Nodes**

The initial calculating for routing cost is for the routing protocol, and we determine linguistics to represent both input and output quantities. For the heuristic routing protocol we defined linguistics “L”, “M”, “ML”, “MH”, “H” and “VH”.

The coverage fraction input is defined the lower boundary to the upper boundary from [0 1] and we use 4 linguistic states to represent all member quantities. Optimum-set values for representing statistics of the coverage fraction input are the function of Triangular [0 0 0.4], Triangular [0 0.3307 0.8307], Triangular [0.2693 0.6693 1], and Triangular [0.6 1 1] are of “L”, “ML”, “MH”, and “H”, respectively.

The relative-speed input uses the relative speed between two nodes by collecting information from HELLO message of neighbors. The relative speed is defined the lower boundary to the upper boundary from [0 100] and uses 3 linguistic states to represent different relative nodes’ speed. Optimum-set values for represent stats of the coverage fraction input are the function of Trapezoidal [0 0 15 0], Triangular [20 50 90], and Triangular [50 100 100] are of “L”, “ML”, “MH”, and “H”, respectively.

The relative-speed input uses the relative speed between two nodes by collecting information from HELLO message of neighbors. The relative speed is defined the lower boundary to the upper boundary from [0 100] and uses 3 linguistic states to represent different relative nodes’ speed. Optimum-set values for represent stats of the coverage fraction input are the function of Trapezoidal [0 0 15 0], Triangular [20 50 90], and Triangular [50 100 100] are of “L”, “ML”, “MH”, and “H”, respectively.

The routing cost is used to represent as the output function. The routing cost is defined the lower boundary to the upper boundary from [0 100] in order to convert to byte and to put into the HELLO message within 8 bits of space of the extended
HELLO message. The cost is defined by 4 linguistic states to represent different levels of the cost. Optimum-set values for represent statistics of the coverage fraction input are the function of Trapezoidal [0 0 15 40], Triangular [11.64 36.64 61.64], Triangular [40 60 80], and Trapezoidal [60 90 100 100] are of “L”, “M”, “H”, and “VH”, respectively.

All input and output functions are defined as linguistic hedges to determine the relationship between inputs and output. In case of unparticular or unrealistic, the rule of linguistic hedge is defined as “VH”. The linguistic hedges are shown below:

RULE 1: If the Coverage Fraction is “L” and the Relative Speed is “L” then the Cost is “L”
RULE 2: If the Coverage Fraction is “L” and the Relative Speed is “M” then the Cost is “M”
RULE 3: If the Coverage Fraction is “L” and the Relative Speed is “H” then the Cost is “M”
RULE 4: If the Coverage Fraction is “ML” and the Relative Speed is “L” then the Cost is “VL”
RULE 5: If the Coverage Fraction is “ML” and the Relative Speed is “M” then the Cost is “L”
RULE 6: If the Coverage Fraction is “ML” and the Relative Speed is “H” then the Cost is “H”
RULE 7: If the Coverage Fraction is “MH” and the Relative Speed is “L” then the Cost is “L”
RULE 8: If the Coverage Fraction is “MH” and the Relative Speed is “M” then the Cost is “M”
RULE 9: If the Coverage Fraction is “MH” and the Relative Speed is “H” then the Cost is “H”
RULE 10: If the Coverage Fraction is “H” and the Relative Speed is “L” then the Cost is “H”
RULE 11: If the Coverage Fraction is “H” and The Relative Speed is “M” then the Cost is “M”
RULE 12: If the Coverage Fraction is “H” and the Relative Speed is “H” then the Cost is “H”

The quality of linguistic cost can represent in the quantitative value by using the most common interpretation means [15], the centroid method, and is evaluated by using Matlab and Mathematica. The routing cost is shown in figure 7.

CASE II: Routing Cost of Collected from Hello Message

In case of collecting routing cost form Hello message in Cost field. That costs in the field is the cost of that node follows (2) and (3).

IV. SIMULATION AND RESULTS

To evaluate the effectiveness of the proposed routing protocol for the real life of vehicle testbed for VANET research makes high cost, so simulation with realistic parameters is feasible for analyzing the fundamental properties

A. Simulation Model and Parameters

We implemented the PHY and MAC based on the IEEE 802.11 MAC protocol standard shown in Table II for the simulation. These parameters used for estimating MAC delay. For signal propagation we use the two-ray path loss model with a transmission range of 300 m. The transmission range was based on the realistic testing of the 802.11a wireless access point.

In the simulation we considered all nodes move in different speed of 40 km/hr and 60 km/hr for different lanes and vehicles surrounded by 50 vehicles or nodes.

Vehicles are randomly placed in the realistic road model of Seria town in Brunei shown in Figure 8 with the total of 500 nodes. All roads are divided into a grid space of 1 m. When nodes move, nodes are placed on the grids with direction along the road in the simulation time. Simulation time has a unit in “tick” where 1 tick is equal to 1 ms. We ran the simulation for testing for 100,000 ms in simulation time unit.

For comparisons, the conventional shortest path or minimum hops using in the conventional OLSR is considered. The minimum hop will have the same condition as the proposed protocol.

Figure 7. The numerical result of the Heuristic Mobility-Aware OLSR protocol.

Figure 8. Realistic Mobility Model (a) Road Model digitized from the satellite image (Google Earth) (b) Shape file to be the road model the road model
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel bit rate</td>
<td>1 Mbps</td>
</tr>
<tr>
<td>Transmission range</td>
<td>300 m</td>
</tr>
<tr>
<td>RTS frame length</td>
<td>160 bits</td>
</tr>
<tr>
<td>CTS frame length</td>
<td>112 bits</td>
</tr>
<tr>
<td>ACK frame length</td>
<td>112 bits</td>
</tr>
<tr>
<td>Slot time ($\eta$)</td>
<td>20 $\mu$s</td>
</tr>
<tr>
<td>Propagation delay</td>
<td>1 $\mu$s</td>
</tr>
<tr>
<td>SIFS</td>
<td>10 $\mu$s</td>
</tr>
<tr>
<td>DIFS</td>
<td>20 $\mu$s</td>
</tr>
<tr>
<td>PLCP preamble + PLCP header</td>
<td>192 $\mu$s</td>
</tr>
<tr>
<td>MAC header</td>
<td>34 octets</td>
</tr>
<tr>
<td>$w_{\min}$</td>
<td>0 slots</td>
</tr>
<tr>
<td>$w_{\max}$</td>
<td>1024 slots</td>
</tr>
</tbody>
</table>

**Table 1. System Parameters in Simulation**

**B. Performance Metrics**

Routing metrics used for evaluating the performance of the protocol according to the following metrics.

*Average end-to-end delay:* many applications are strict on the maximum tolerable delay in serious applications such as the collision warning of vehicles on the road. It causes the number of disconnection in serious applications such as traffic report. The end-to-end delay is calculated from the SRC starting to send data packets to the DST thorough all packets [16].

*Throughput:* the throughput is defined as metrics in term of data packet received successfully (packets/s).

*Number of Disconnection:* the numbers of disconnection is used to measure numbers of disconnection happened from nodes in the route changing mobility or their coordinate. When the route suffers from the disconnection, the packet cannot send to the destination and has to reconstruction the route again.

**C. Results**

In simulation, we observed the number of nodes compared to MAC delay within a node varied from 2 nodes up to 500 nodes with a packet size of 1024 bytes and the contention-window sizes of 1024 and the arrival packet of 1 packet/s as illustrated in Figure 9. Since the MAC delay is relying on the number of competitor, the lower the MAC means there is less contentious occurring on each transmission attempt. As considered in number of hops shown in Figure 10, we found that the numbers of hops of the proposed protocol are comparable to the minimum hop algorithm because both protocols are used the transmission range is used as a parameter. The transmission range is determined to equal for all nodes during the simulation time. In reality, transmission range of each node may depend on many effects such as path loss surrounded nodes, the RSSI of the received node, the transmission power sent out from the transmitted node, etc. The different of the proposed protocol to minimum hops is that the relative speed between two nodes is taken into account as a parameter. The relative speed between to node is effect directly to the link lifetime of the link. The more the different speed the less the link lifetime. As we observe in Figure 11, we found that the number of disconnection of the link of the minimum hop is greater than the propose protocol because the minimum hop is not considered the different speed. So when the minimum hop selects nodes in the link, the minimum hop protocol will not consider the speed of nodes. If selected nodes in the link of the minimum hop protocol select nodes those are greater different in speed, the connection of the link will disconnected easily. In proposed algorithm, the link lifetime is greater than the minimum hop, because the relative speed between two nodes are taken into account as a parameter. So the proposed algorithm is aware in the link lifetime caused by the speed variation. As seen in Figure 11 the disconnections of the minimum hop happen at time 18s, 46s and 83s. In the proposed protocol, the disconnections happen at time 51s and 83s.

Results of throughput and the cumulative throughput illustrates in figure 12 and figure 13, respectively. The throughputs of the minimum hop are both comparable and higher than the proposed protocol because if we consider the compare to the time that throughputs are higher, the minimum hop has numbers of hops less than the proposed protocol. During throughputs are comparable numbers of hops in the link are the same and a little bit different happened from MAC delay. In some simulation time the throughputs of both protocols are decrease rapidly caused by the disconnection of the link. As we consider the cumulative throughput, we found that the minimum hop protocol has cumulative throughputs grater than the propose algorithm, but the propose protocol is linearly increase in cumulative throughputs that mean the link of the will be stable and will not change much.
V. CONCLUSION

In this paper, we present a new routing protocol, name as the mobility-aware OLSR protocol, which can provide a stability route for VANET. The precise of MAC delay of CSMA/CA protocol is estimated. Referring from the MAC delay, buffer delay without queue in the system and system throughout, the proposed protocol is comparable to the minimum hop. When the node move in different mobility the minimum-hop route will disconnect greater than the proposed protocol, because the minimum hop only consider the hops that are minimum. When some nodes in the route have different speed the route will disconnect depended on the relative speed of nodes. But in the proposed routing hop-by-hop will be consider both the relative speed of nodes and the route that is the minimum. In reality the nodes have different in speed and course, the minimum hop might not work for VANET.

REFERENCES


