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# Improving Relay Selection Scheme for Connecting VANET to Internet over IEEE 802.11p

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## ABSTRACT

Vehicular ad hoc networks (VANETs) enable vehicles to communicate with each other (V2V) as well as with roadside infrastructure units (V2I). These units provide different services such as driver information systems and Internet access. When one node will connect to the Internet, first it must discovery the route to these units. Based only on mobility parameters, we can select longest life time routes to routing packet, but these routes may be with low quality of signal. So, a dropping packet and enforcing retransmission will be certainly happened. For that reason, we propose, in this paper, an efficient routing protocol that improve relay selection scheme by considering link life time and quality of signal as parameters of relay selection, in order to make vehicles able to select longest life time and best quality of signal route to the roadside units. Our relay selection scheme consists to select next forwarding node based on predicted life time of links, received signal strength indicator (RSSI) and signal to interference-noise rate (SINR). The objective is to be sure that data packets will be routed on longest life time, highest received signal strength and strongest routes. The simulation results show that the proposed protocol enhances throughput and decreases the packet loss and overhead with comparable end to end delay.

### General Terms

VANETs, routing, Internet Access

### Keywords

Vehicular ad hoc Networks, routing, lifetime, quality of signal, RSSI, SINR, RSUs

## 1. INTRODUCTION

Many applications make use of vehicular ad hoc networks (VANETs), such as traffic management, driver information system and Internet access. Several works are proposed to connect VANETs to Internet [8, 9]. The vehicles can be connected to the Internet on the road by locating the gateways along the highway road, in point of interest or in the urban area, which are equipped with 802.11p technologies, called roadside unit (RSUs) which are part of the Internet. Each vehicle is equipped with computing technologies and wireless communication devices called on board units (OBUs).

IEEE 802.11p [1], also known as Wireless Access in Vehicular Environment (WAVE) protocol is an enhancement to the 802.11 physical layer (PHY) and medium access control sub layer (MAC) to support high vehicular mobility, faster topological changes. The data rate values witch are available in 802.11p ranging from 3 to 27 Mbps, and a short-range radio communication of approximately 300 m. The 802.11p operates at a frequency of 5.9 GHz, divided into seven 10 MHz-wide channels available in the frequency band of 5.85-5.925 GHz allocated for the Dedicated Short Range Communication (DSRC) in vehicle to infrastructure (V2I) and vehicle-to-vehicle (V2V) communication. IEEE 802.11p cooperates with the IEEE 1609 family [15], covering higher protocol layers, to define a standard protocol stack for vehicular environments. A high vehicular speed can cause frequent disconnection between nodes, the large number of vehicles on the road can flood the VANETs network by broadcasting messages which will increase overhead. In congested and more realistic environment scenario, when the number of vehicular sources increases, interference, noise and access channel contention increases as well.

In this work, we propose a new routing protocol which improve relay selection scheme by combining mobility and quality of signal parameters, to select next hop. This scheme consists, in one side, to predict lifetime of links based on stability parameters (e.g.,speed, direction and location), in order to select a most stable route. In the other side, it consists to measure RSSI and SINR for received packet, in order to discovery the best signal quality route. Therefore, the objective of proposed routing protocol is to provide Internet connectivity to the vehicles by reducing overhead during the gateway discovery and selecting the most stable and highest quality of signal route.

We will use a hybrid gateway discovery that combines the advantages of proactive and reactive approaches to providing connectivity, limiting broadcasts to a predefined zone. The advertisement message is broadcasted by some particular nodes called relay in this zone.

The rest of the paper, is structured as follows. In Section II we present the related work. The proposed work is detailed in Section III. The performance of proposed protocol is discussed in Section IV. Finally, we give the conclusion and future work directions in Section V.

## 2. RELATED WORK

There are a several contributions in the open literature for connecting VANETs to Internet. In general these contributions are divided on two categories, there are protocols based to stationary gateway (RSUs) and the other are based to mobile gateways.

In the research work [2], the authors proposed an efficient routing protocol for connecting vehicular networks to the Internet which uses the characteristics of vehicle movements to predict the future behaviour of vehicles, and to select a route with the longest lifetime. The proposed protocol aims to broadcast the advertisement messages through multi-hops in the predefined zone and uses a distributed manner to select relay for re-broadcasting message, this approach will connect VANETs to Internet on minimizing overhead without flooding network through most stable route.

In the paper [3], the authors proposed a new approach witch integrate VANET with 3G technology in order to connect VANET to Internet. The proposed approach is based on two mechanisms , a dynamic technique to cluster vehicles according to defined criteria and an adaptive management of mobile gateways. The clustering is performed on two steps, the first step consists to cluster vehicles depending on their relative direction to 3G active regions of base station, the second step for clustering consists to form subclusters by the mobile gateways that are within range in each other and that have the receive strength signal (RSS) with respect to the base station is greater than a defined limit. The discovery gateways can be done proactively by broadcasting periodically advertisement messages from gateways or reactive by broadcasting solicitation message from sources vehicles. A mobile gateway is selected from other if the RSS with respect to the base station and the stability of the link relative to the source vehicle are higher than the fixed threshold that are specific to each cluster and these two parameters are also better than those of other gateways. This approach avoids saturating base stations allowing just certain vehicles to communicate directly with them. The clustering also allows vehicles to better manage the inter-vehicle communications and thereby mitigate the effect of the redundancy control messages. Also coupling the high data rates of 802.11p-based VANET and the wide coverage area of 3G/UMTS allows vehicles to communicate with UMTS base station using high data transmission rate via large distance.

In the research work [4], the author proposed a framework based on the inter layer network cooperation to provide vehicular users with the best available Internet access. This framework consists to estimate in the MAC layer some parameters (expected delay and available throughput) and use them in the network layer, in order to select route with the minimum bit rate requirement and the residual delay allowed to be spent from the gateway to the destination. The routing layer of each VANET node cooperates also with physical layer to get information about the QoS performance of the route and about its reliability. At the PHY layer, each node in VANET measures periodically, the received signal strength indicator (RSSI) on each active link to their neighbours, in order, to select most stable route. Simulations in urban scenarios showed that the proposed approach achieves improved performance, mainly in terms of effectiveness of procedures of path-to-the-gateway discovery and maintenance, and end-to-end QoS provisioning.

## 3. PROPOSED WORK

The present contribution consists to implement a new routing protocol, in order to improve relay selection scheme by combining the mobility and quality of signal parameters. This will allow to routing data packet in the most stable and strongest signal route in VANETs. Consequently, the suggested approach will enhance significantly the metric network in term of throughput, delay and overhead in the network, due to the decreasing of frequent disconnection and packet loss.

### 3.1 Relay Selection Metrics

(1) Link expiration time

The Link Expiration Time (LET) is the estimated period that two nodes maintain connection between them in the VANET network. Each vehicle in the VANET can predict a LET using the location and mobility information provided by GPS [8], for this, we suppose that vehicles are equipped with GPS devices, therefore, if we know position, speed and direction parameters of two neighbours nodes, we can predict the period of time that the connection can be maintained between these two nodes. The objective of this metric is to select a most stable link between two vehicles. This parameter will be more effective than the others, due to the nature of proposed protocol.

We consider two vehicles $i$ and $j$ which identify by coordinates $(x_i, y_i)$ and $(x_j, y_j)$ and move in directions $\theta_i$ , $\theta_j(0 \leq \theta_i, \theta_j < 2\pi)$ with speed $v_i$ and $v_j$ at an instant, respectively, and we consider also $R$ be the wireless transmission range of nodes. According to [2] the LET can be estimated basing on the following formula :

$$LET_{ij} = \frac{-(ab+cd) + \sqrt{(a^2+c^2)R^2 - (ad-bc)^2}}{a^2+c^2} \quad (1)$$

where,
$a = v_i \cos\theta_i - v_j \cos\theta_j$
$b = x_i - x_j$
$c = v_i \sin\theta_i - v_j \sin\theta_j$
$d = y_i - y_j$.

Our relay selection scheme (as explained in the next section) needs a function, which lies each element in $]0, \infty]$ to its image in $]0, 1]$. For this purpose, we take advantage to exponential weighted moving average with smoothing factor and formulas proposed in [6].

Upon reception advertisement message which include the source movement information, the receiver computes LET according to the formula 1, and then calculates the average link expiration time $\overline{\mathrm{LET}}$ based on the LET , using an exponential weighted moving average with smoothing $\alpha_{\mathrm{LET}}$ as shown in the formula 2.

$$\overline{\mathrm{LET}}_{\mathrm{c}} = \alpha_{\mathrm{LET}}.[1 - \frac{\mathrm{LET}_{\mathrm{thresh}}}{\mathrm{LET}_{\mathrm{c}}}] + (1-\alpha_{\mathrm{LET}}).\overline{\mathrm{LET}}_{\mathrm{p}} \quad (2)$$

where $\overline{\mathrm{LET}}_{\mathrm{c}}$ and $\overline{\mathrm{LET}}_{\mathrm{p}}$ are the average LET computed from the current receiver and previous sender respectively. $\mathrm{LET}_{\mathrm{thresh}}$ is the LET threshold which represent the minimum acceptable value of link lifetime. $\overline{\mathrm{LET}}_{\mathrm{p}}$[1] is included in the advertisement message sent by the sender. Now, let $\mathrm{R_k}$ the route from the RSU to the source vehicle , and in each route $\mathrm{R_k}$ there are $\mathrm{n}-1$ links between $\mathrm{n}$ vehicles, $\mathrm{R_k} = \{(\mathrm{V_0}, \mathrm{V_1}), ..., (\mathrm{V_{n-2}}, \mathrm{V_{n-1}})\}$ where $\mathrm{V_0}$ is the RSU and $\mathrm{V_{n-1}}$ is the source vehicle. The route expiration time is defined to be the shortest lifetime along the route we write :

$$\mathrm{RET}(\mathrm{R_k}) = \min_{\mathrm{i=1}}^{\mathrm{n-1}} \mathrm{LET}(\mathrm{V_{i-1}}, \mathrm{V_i}) \tag{3}$$

As mentioned in [2], to find RET, we base on sequential approach. For example in **Fig.**1, the vehicles $N$ and $M$ are selected as relays to construct the route from RSU to vehicle $I$. The LET of each link is written over the link. $RET_I$ is its route expiration time witch equals 7.5s in this case. The vehicle $I$ in this example is selected as a next relay and will rebroadcast the message to its neighbors such as $J$, $K$ and $L$.

(2) Distance rate

Upon reception of advertisement message from one vehicle $i$ (RSU or previous relay), a vehicle $j$ computes a distance rate ($DR_{ij}$) which is defined in [6] as follow :

$$DR_{ij} = \frac{d_{ij}}{R} = \frac{\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{R} \tag{4}$$

where $(x_i, y_i)$ and $(x_j, y_j)$ are the Cartesian coordinates of vehicles $i$ and $j$ determined by GPS, and $R$ is a maximum transmission range. Here we assume that every node has the same transmission power and that the transmission power is constant. We will integrate this parameter in the relay selection, in order to select a shortest route in term of hops, between RSU and source vehicle.

(3) Received Signal Strength Indicator

In this paper, we thank to improve the relay selection by considering the quality of received signal. The main quality of service (QoS) parameter is the Received Signal Strength Indicator noted RSSI, which measures the signal strength of the received packets. This parameter is a function of the distance between the node and its gateway or between two neighbours and can be used to detect that a link is going down. However the RSSI also depends on the environment, interference, noise, channel propagation properties, antenna design. A drop of the RSSI does not necessarily mean that the node is about to leave its neighbour node coverage, but it can be due to temporary interference for example. Noted that RSSI can be used to predict life time of link as it is in research work [4]. In this paper, the proposed protocol will be evaluated in more realistic environment using a Nakagami model propagation.

To ensure that the packet will be received with enough reception power strength, the RSSI must be considered in the relay selection scheme.

Upon reception of advertisement message from RSU or previous relay, a vehicle measures the RSSI, and then computes the average Received Signal Strength Indicator $\overline{\mathrm{RSSI}}$, which is obtained from RSSI through an exponential weighted moving average with smoothing $\alpha_{\mathrm{RSSI}}$ as the follow formula shown.

$$\overline{\mathrm{RSSI}}_{\mathrm{c}} = \alpha_{\mathrm{RSSI}}.[1 - \frac{\mathrm{RSSI}_{\mathrm{thresh}}}{\mathrm{RSSI}_{\mathrm{c}}}] + (1 - \alpha_{\mathrm{RSSI}}).\overline{\mathrm{RSSI}}_{\mathrm{p}} \tag{5}$$

where $\overline{\mathrm{RSSI}}_{\mathrm{c}}$ and $\overline{\mathrm{RSSI}}_{\mathrm{p}}$ are respectively, current node (receiver) and source of message average RSSI measures. $\mathrm{RSSI}_{\mathrm{thresh}}$ is the received signal strength threshold. The $\overline{\mathrm{RSSI}}_{\mathrm{p}}$[1] is included in the advertisement message sent from the source.

(4) Signal to Interference-Noise Rate

An other signal quality metric have been considered in this work, it calls Signal to Interference-Noise Rate (SINR). A node having high SINR, means that it has the ability to decode information from arrived radio waves.To select the route with low packet loss, the SINR must be considered in the relay selection scheme. More than the SINR is higher, more than signal quality is better, therefore high probability of having a low packets loss in the selected route.

When receiving advertisement message, a vehicle measures the SINR, and then computes the average Signal to Interference-Noise Rate $\overline{\mathrm{SINR}}$, which is obtained from SINR measured, through an exponential weighted moving average with smoothing $\alpha_{\mathrm{SINR}}$ as the follow formula shown.

$$\overline{\mathrm{SINR}}_{\mathrm{c}} = \alpha_{\mathrm{SINR}}.[1 - \frac{\mathrm{SINR}_{\mathrm{thresh}}}{\mathrm{SINR}_{\mathrm{c}}}] + (1 - \alpha_{\mathrm{SINR}}).\overline{\mathrm{SINR}}_{\mathrm{p}} \tag{6}$$

where $\overline{\mathrm{SINR}}_{\mathrm{c}}$ and $\overline{\mathrm{SINR}}_{\mathrm{p}}$ are the average SINR computed respectively, from the current receiver and source node of message. $\mathrm{SINR}_{\mathrm{thresh}}$ is the SINR threshold fixed according to the physical data rate used. The $\overline{\mathrm{SINR}}_{\mathrm{p}}$[1] is included in the advertisement message sent from the source.

### 3.2 Relay Selection Scheme

Efficient and reliable relay node selection is important for providing multi-hop broadcast services in vehicular ad hoc networks. The relay selection scheme as in [2] is completely in a distributed method. Each vehicle can know from the supported information in received message, if it will become relay or no. This method helps in reducing the overhead and collisions in the network; future broadcast messages will not flood the network, and this prevents broadcast storms from happening.

The selection of the next hop is performed by mean of the Contention Based Forwarding (CBF) suggested in [10]. The authors based on results obtained by a proposed progress function that satisfied some requirement in their work, and they set the timer based on the given result. For the contention process, CBF makes use of biased timers. In this work, we need to create another new function that will take into account our requirements based on all metrics explained previously. For this purpose, we should combine the $\overline{\mathrm{LET}}$, $\overline{\mathrm{RSSI}}$, $\overline{\mathrm{SINR}}$ and DR together. However, $\overline{\mathrm{LET}}$ should not be as effective as the remaining parameters for next hop selection. To define the replacement function for CBF which combine all these metrics, and reduce the effect of other parameters, we take advantage to weighted mean with factor $\alpha$, The new function denoted $F$ is defined as follow :

$$F = \alpha.\overline{\mathrm{LET}} + \alpha(1 - \alpha).\overline{\mathrm{RSSI}}.\overline{\mathrm{SINR}} + (1 - \alpha)^2.\mathrm{DR} \tag{7}$$

where $\alpha$ may be selected in $]\frac{1}{2}$,1] to give more weight for function $\overline{\mathrm{LET}}$ than $\overline{\mathrm{RSSI}}$ and $\overline{\mathrm{SINR}}$. In the one side, this function takes into account all parameters such as LET, DR, RSSI and SINR. On the other side, it will reduce the packet duplication that can be occurred when two or more vehicles have a close link lifetime which is the main parameter of selection. For the contention based on the result of this function, we select runtime timer as in [2] as follow:

$$t(F) = T \times (1 - F) \tag{8}$$

[1] $\overline{\mathrm{LET}}_{\mathrm{p}}$, $\overline{\mathrm{RSSI}}_{\mathrm{p}}$ and $\overline{\mathrm{SINR}}_{\mathrm{p}}$ initialized to zero.

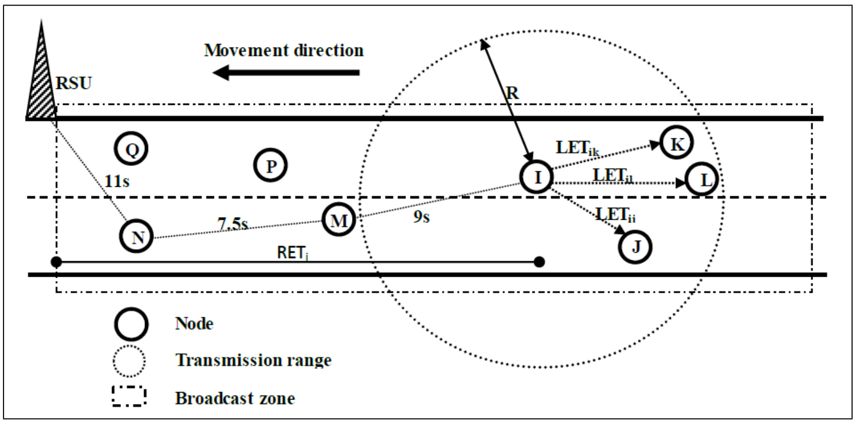


Fig. 1. Stable route selection example

where $0 \leq F \leq 1$, $t(F) \in [0, T]$ and T is the maximum forwarding delay.

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**Algorithm 1** Relay Selection and Rebroadcasting

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PART I : Receving Message
When a vehicle $i$ receives RSU_ADV message:
it computes LET and DR according to information included in the message;
it measures RSSI of received packet;
it measures SINR of received packet;
**if** (Vehicle $i$ is in broadcast zone) **then**
  **if** ((LET computed $>$ LET_THRESH) & (RSSI computed $>$ RSSI_THRESH) & (SINR computed $>$ SINR_THRESH)) **then**
    it computes $\overline{\text{LET}}$ according to (2);
    it computes $\overline{\text{RSSI}}$ according to (5);
    it computes $\overline{\text{SINR}}$ according to (6);
    Timeout=it computes a waiting time according to (8);
    The vehicle runs its timer;
  **else**
    The vehicle drops message;
  **end if**
**else**
  The vehicle drops message;
**end if**
PART II : REBROADCASTING MESSAGE
**if** (Vehicle does not receive the same message during a waiting time) **then**
  new RET = min(LET computed, RET extracted in the message);
  $\overline{\text{LET}}_{\text{p}}$=$\overline{\text{LET}}_{\text{c}}$ ; $\overline{\text{RSSI}}_{\text{p}}$=$\overline{\text{RSSI}}_{\text{c}}$ ; $\overline{\text{SINR}}_{\text{p}}$=$\overline{\text{SINR}}_{\text{c}}$;
  Update message with new values;
  RSU_ADV(RSU,Relay=vehicle $i$, SeqNum, $\theta_i, v_i, x_i, y_i$, new RET,$\overline{\text{LET}}_{\text{p}}$,$\overline{\text{RSSI}}_{\text{p}}$,$\overline{\text{SINR}}_{\text{p}}$);
  The vehicle rebroadcasts RSU_ADV message;
**else**
  The vehicle cancels its timer and discards both messages;
**end if**

---

As detailed in Algorithm 1, when receiving a message, a vehicle will wait for the amount of time that is computed by the timer, before re-broadcasting the message. If during this time it receives a message originated from the same gateway with the same sequence number (means that is another vehicle has re-transmitted the message), it will cancel the timer and discard both messages. Otherwise, it rebroadcasts the message after the timer has expired and decides that it becomes relay.

In order to not flooding the VANET network, and decreasing the overhead, only the vehicles selected as relays having the right to rebroadcast the advertisement message to other vehicles . As in ODAM [2] each node schedule transmission, and when one node wins to be a relay, it rebroadcasts and suppresses other nodes from rebroadcasting the same message.

### 3.3 Gateway discovery mechanism

Internet access is provided by gateways located in the long of road called Road Side Unit (RSU). To extend Internet connectivity to vehicles, they initially need to discovery a route to communicate with them,for this, an efficient gateway discovery mechanism is required. As proactive gateway discovery reduces delay and reactive discovery reduces signaling overhead,our work envisages a hybrid gateway discovery mechanism for VANET as in [2, 3, 5].

Each RSU advertises periodically, within predefined zone its current parameters such as its address, relay address initialized by RSU address, message sequence number, geographic parameters of predefined broadcast zone, and estimated route expiration time (RET) initialized by a large value, these parameters will be included in message called Road Side Unit Advertisement message (RSU_ADV). The gateway discovery aims at propagating this message using intermediates nodes in this zone. When a vehicle receives the massage RSU_ADV, if it is selected as relay, it compares its LET with RET included in the message, if the LET is less than RET , the new RET is set to the LET of the relay, then the relay updates these parameters in its routing table as well as in the RSU_ADV message and broadcasts the message. The message is forwarded until last vehicle belonging to broadcast zone.

If one vehicle doesn't receive any message from RSU or its neighbors, a reactive discovery must be executed. In this case a RSU solicitation message (RSU_SOL) is broadcasted by exactly the same mechanism as RSU_ADV until it is received by a RSU or any vehicle that is already aware of a route to a RSU. If a vehicle is already connect to the RSU, it sends an unicast RSU_ADV message

Table 1. Simulation Environment Parameters

| Parameter | Value |
|---|---|
| Mobility Model | Highway |
| Highway length | 3000m |
| Number of lanes | 2 lanes |
| Maximum speed | 10, 20, 30 and 40 m/s |
| Number of nodes | 40, 60, 80 and 100 |
| Number of RSUs | 2 (no handover) |
| Distance between RSUs | 1000m |
| Simulation time | 300 s |
| Channel | Channel/WirelessChannel |
| Propagation model | Propagation/Nakagami |
| Network Interface | Phy/WirelessPhyExt |
| MAC | Mac/802_11Ext |
| Interface queue | Queue/DropTail/PriQueue |
| Antenna Type | Antenna/OmniAntenna |
| Max packet in interface queue | 50 |
| Transmission range | 300 m |
| Traffic type | TCP |
| Packet size | 1000 bytes |

to the sender of the RSU_SOL message. Before sending an unicast RSU_ADV message, the vehicle compares its RET of its most stable route to the RSU with the RET integrated in the RSU_SOL message, the minimum of them is the value of the RET that will be included in the unicast RSU_ADV. On receiving of the unicast RSU_ADV message, the vehicle updates its routing table. It can happen that the source vehicle receives more than one replay from different RSUs or from a same RSU but with different routes,in this case the most stable route will be selected. If the routes are equal in term of stability,the source selects the highest RSSI, in case the tie the route with the minimum number of hop will be selected.

## 4. PERFORMANCE EVALUATION

To evaluate the performance of proposed approach, we have implemented our routing protocol in Network Simulator NS2.33.We have compared AODV+ with proposed protocol. AODV+ [11] is modified for connecting mobile ad hoc network to wired network. We perform some simulations in order to evaluate the proposed protocol in term of throughput, packet end to end delay, overhead and packet loss rate by investigating the impact of varying the mobility of nodes and density of nodes on the road.

### 4.1 Simulation environment

In this present work, we have based on the papers [13, 14] to give insights on some measurements of the IEEE 802.11p MAC and physical layer using NS2 [18]. The simulation is also configured to use the Nakagami propagation model with its highway parameters because it is best for simulation of a WAVE environment as said in the paper [14]. The data rate is fixed to 3Mbit/s. Using MOVE [17] and SUMO [16], we have created a highway scenario of 3000 m with two lanes. All vehicles move from the one end of the highway to other end in the same direction. The table 1 provides a summary of all these simulation environment parameters.As in the paper [2],we have scheduled RSU to broadcast the advertisement message every 5s in the predefined broadcast zone which has been considered to be a circle with a radius of 1000m and we set T to 3.75ms.

Concerning smoothing factors $\alpha_{LET}$, $\alpha_{RSSI}$ and $\alpha_{SINR}$ , we have fixed all them to 0.8, after a lot of experiments and analysis, and $\alpha$ gives good result when it tackes value 0.7.

Each source vehicle sends data packet (request) to one node located in the wired network (i.e server), when wired node receives the data packet sent from source, it will replay the source vehicle by sending an other data packet as response. The performance of proposed protocol is evaluated using the following metrics : throughput, packet end to end delay and overhead.

—The throughput is defined as average rate of the total number of bytes received in the application level network over total time between start and end time of communication.
—The average end to end delay is the time required for each data packet (sent by wired node as replay) to reach source vehicle from RSU.
—The normalized routing overhead is the rate of the total number of control packets generated by each protocol, normalized by total number of received packets.

### 4.2 Simulation results

In this section, we present the analyses of performance of proposed protocol comparing it with AODV+.

(1) Impact of number of vehicles

To see the effect of varying the number of nodes in the network, we fixed the maximum speed on 15m/s and the number of source vehicles on 20 vehicles.

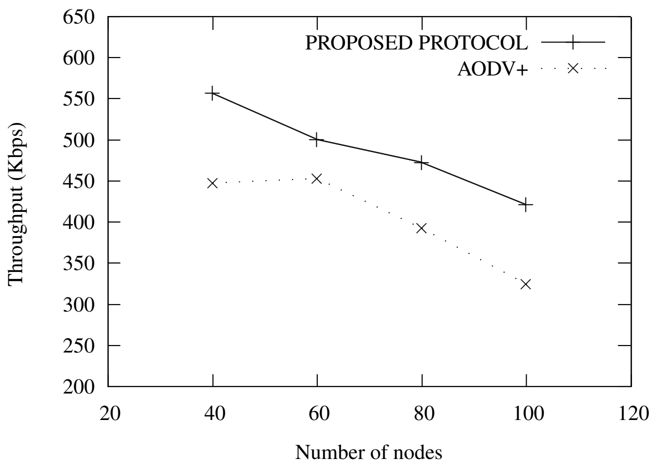


Fig. 2. Average throughput vs. number of vehicles

The Fig.2 shows the average throughput result varying number of vehicles in the road. We observe that a proposed protocol improves significantly the throughput compared to AODV+. We observe in this figure that proposed protocol has slightly higher throughput values when the number of nodes increases. The proposed protocol outperforms the protocol AODV+ ,because more than it uses stability metric to select most stable route, it considers also quality of signal such as, RSSI and SINR, to select the highest signal quality route, as result the lowest packet loss and highest throughput route is selected.

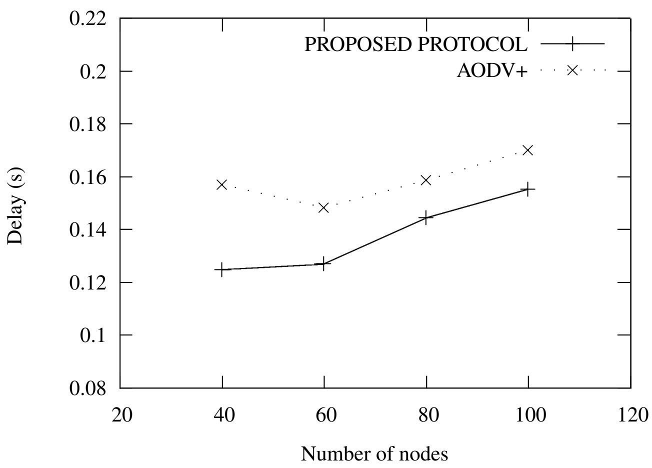


Fig. 3. Average end to end delay vs. number of vehicles

The Fig.3 depicts the average end-to-end delay experienced by data packets for varying node density. As it is shown, a proposed protocol provides considerably lower delays compared to AODV+. Reason behind the reduction in end to end delay is because of the considering of signal quality which will discarded weaker signals at the routing layer. This makes only selected signals entering into further processing phase thus reducing the end to end delay. This delay value given by proposed protocol is quite acceptable, seeing the amount of throughput that is able to maintain. Generally, the result of average end to end delay given by proposed protocol outperforms AODV+.

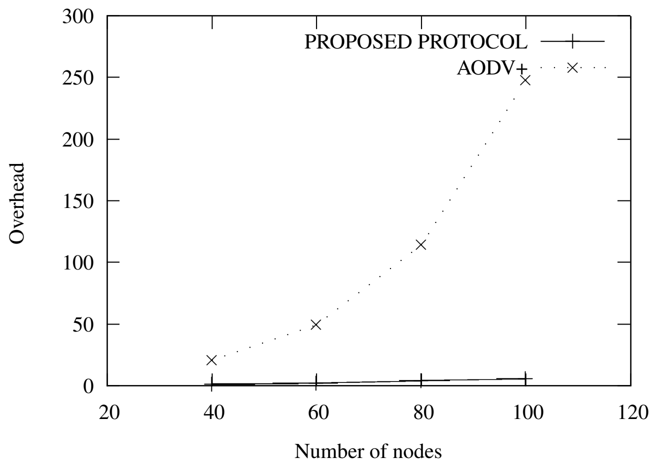


Fig. 4. Normalized routing overhead vs. number of vehicles

We will now compare the overhead results between the proposed protocol and AODV+.The result of this comparison is illustrated by Fig.4. The figure shows that proposed protocol reduces significantly the overhead. However, the AODV+ generates more overhead when the number of nodes increases. This outperformance of proposed protocol is due to the efficient relay selection scheme which select only some particular nodes to rebroadcast control message, unlike to AODV+, each node in the network rebroadcasts control message.

(2) Impact of number of source vehicles

To study the impact of varying the number of source vehicles in the network, we fixed the number of nodes on 100 nodes and the maximum speed on 15m/s.

The Fig 5 shows throughput result on varying the number of source vehicles. By increasing the number of vehicles that will connect to Internet, the average throughput decreases accordingly, in AODV+ and suggested protocol. As shown in Fig 5, the proposed protocol outperforms AODV+ in term of average throughput. The reason of this result is that proposed protocol considers a RSSI and SINR parameter as one relay selection metrics, this helps to route data in highest received signal strength and strangest signal route, as result, the dropped packets will be reduced and the data throughput will be increased.

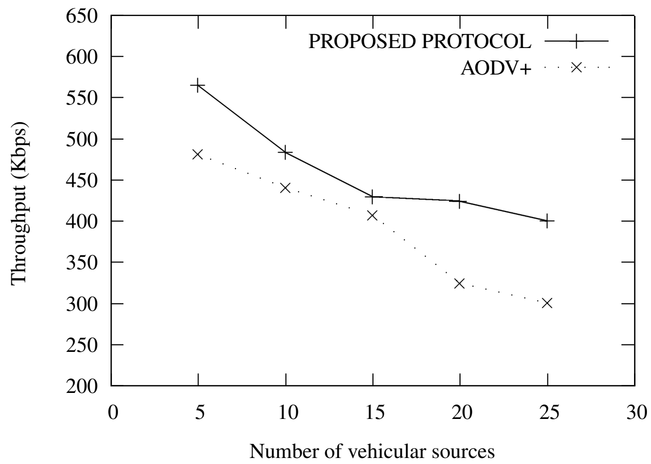


Fig. 5. Average throughput vs. number of source vehicles

The Fig.6 shows the average packet delay result. We can observe that, proposed protocol, gives a lowest values compared it with AODV+ by increasing the number of source vehicles. Our protocol's average end to end delay increases relatively, reaching maximum value $0.15528s$ for 20 vehicular sources and minimum value $0.11139s$, for low number of source vehicles (5) in this scenario. Our protocol result for average end to end delay are very acceptable seeing data throughput provided in the network.

The graph, shown in Fig.7, represents the control overhead result with different number of vesicular sources.The graph shows that by increasing the number of source vehicles, the overhead increases accordingly, in AODV+ and it is relatively stable (Slight change) in very low values in proposed protocol. The reason is the efficient and reliable relay selection mechanism adopted for proposed protocol. We observe that proposed protocol reduces significantly the overhead needed to establish the route for connection to the Internet.

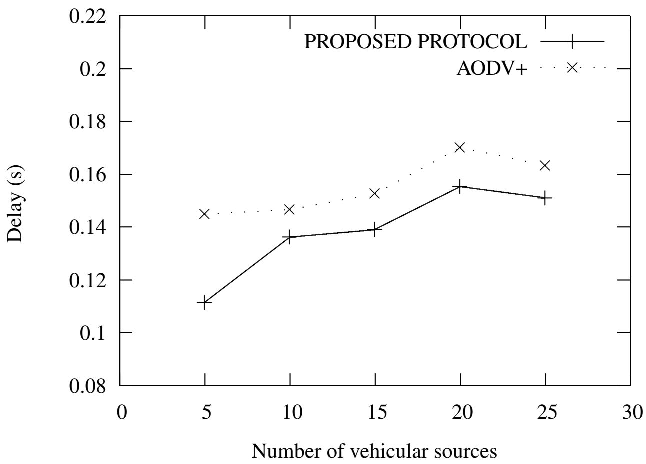


Fig. 6. Average end to end delay vs. number of source vehicles

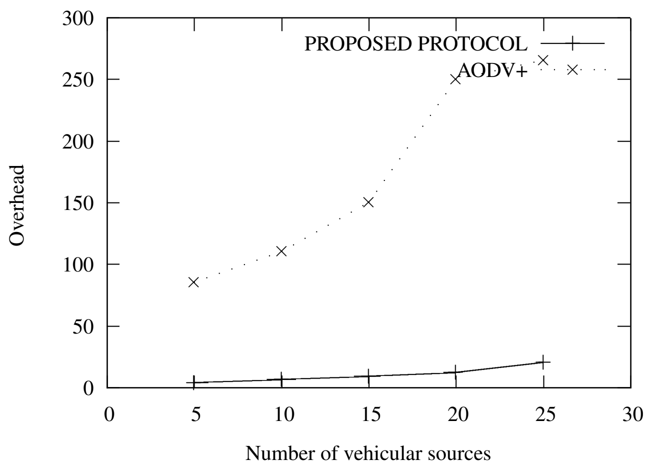


Fig. 7. Normalized routing overhead vs. number of source vehicles

(3) Impact of speed

To study the impact of varying the maximum speed in the network, we fixed the number of nodes on 100 nodes and the number of vehicular sources on 20 sources.

The Fig.8, Fig.9 and Fig.10 represent the result of varying the speed of vehicles. Increasing the vehicles movement in the road will cause a smaller link lifetime between vehicles,and eventually having less stable routes. This will maximize the failure frequency of routes and thus increase the number of dropped packets.

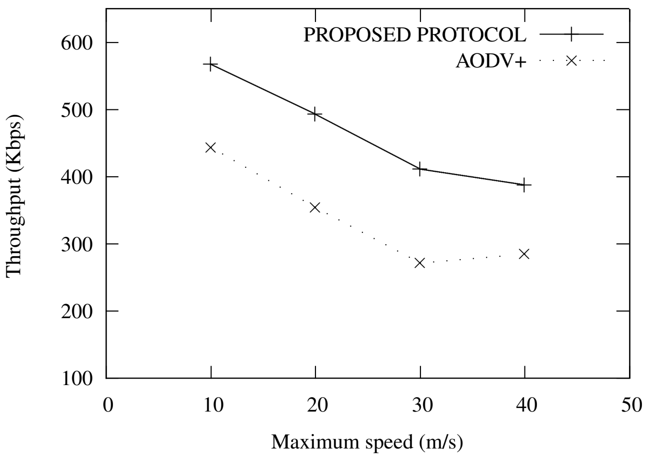


Fig. 8. Average throughput vs. maximum speed

The Fig.8 shows that the data throughput decreases as the maximum speed increases for all protocols,due to the failure frequency of routes caused by fast movement of vehicle, as result a smaller lifetime of links, this will increase a packet loss rate. As it is observed, proposed protocol provides a highest value of data throughput in the contrast with AODV+ for different speed. Reason behind the increase of data throughput is because that proposed protocol controls mobility of nodes by considering LET in order to find the most stable route. In the other hind, the suggested protocol takes into account quality of signal by considering RSSI and SINR, in order to select the strangest signal route. In general our experiments show that proposed protocol performs better in terms of throughput than AODV+, under different value of speed.

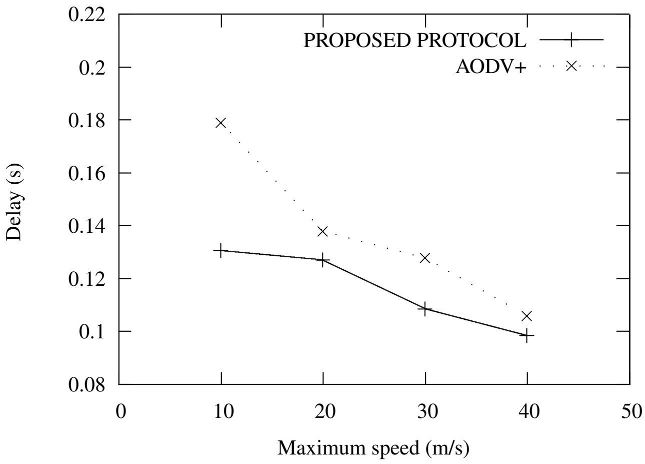


Fig. 9. Average end to end delay vs. maximum speed

The Fig.9 depicts the result of average packet delay, varying the maximum speed. In the maximum speed range 10-40m/s, the suggested protocol has a lowest values in term of end to end delay. Reason behind the reduction in end to end delay is because of the selective processing of signals. Only received signals which have RSSI and SINR values exceed respectively a fixed thresholds, will be treated at the routing layer thus, reducing the end to end delay. In the contrast, AODV+ has a highest values of packet delay, this, it can be explained that the protocol AODV+ bases on the number of hop to limit advertisement message instead of geographic parameters. So for AODV+ the message can be propagated outside of advertisement zone, which will add a large delay to the packet. Generally, our protocol outperforms the AODV+ in term of end to end delay.

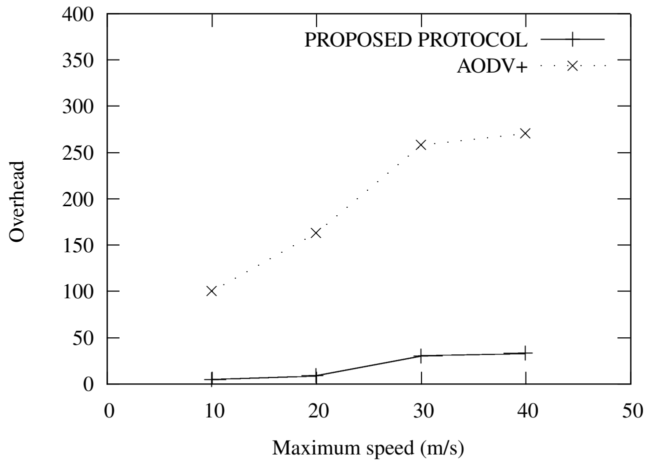


Fig. 10. Normalize routing overhead vs. maximum speed

By increasing the maximum speed, as it is shown in Fig.10 the normalized routing overhead increases for both protocols, our protocol and AODV+. Comparing it with AODV+, we can say, that our protocol reduce significantly the number of control messages needed to establish stable routes, thus it will decrease the used bandwidth in the network,therefore the data will be transmitted with high throughput in the proposed protocol.

## 5. CONCLUSION AND FUTURE WORK

In this paper, we present a new routing protocol to connect VANETs to Internet, which integrates a link stability between different vehicles based on the vehicle movement parameters and link signal quality. The first is used to find links maintaining connection a long time, the second is used to select the strengest link in term of RSSI and SINR. By combining these both metrics the routes selected for communication between vehicles and RSUs will be the most stable and lowest packet loss routes. Also an efficient relay selection and rebroadcasting scheme is introduced in proposed protocol based on contention based forwarding. Simulation results have shown that our protocol outperforms AODV+, we also observe, that integration of quality of signal has improved network performance in terms of data throughput, packet delay, overhead and packet loss. In future work we plan to evaluate our protocol in more realistic environment by increasing the number of nodes (up than 100). Long highway scenarios need to install many RSUs along the road,and hand over the connection from one RSU to an other must be executed, we will implement the handover mechanism in our protocol. A one relay might get overloaded if the number of relay requests exceeds the service capacity of the vehicle, a relay serving a large number of vehicles might become a bottleneck eventually dropping the packets and enforcing retransmissions, in the future, we will integrate our protocol with an efficient control overload of relay.

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