Research Journal of Applied Sciences, Engineering and Technology 7(14): 2935-2945, 2014
DOI:10.19026/rjaset.7.624
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: July 1, 2013 Accepted: October 31, 2013 Published: April 12, 2014

Research Article

An Enhanced Connectivity Aware Routing Protocol for Vehicular Ad hoc Networks

Ahmadu Maidorawa and Kamalrulnizam Abu Bakar
Faculty of Computing, Universiti Teknologi Malaysia, 81310, UTM Johor Bahru,
Johor Darul Ta'azim, Malaysia

Abstract: This study proposed an Enhanced Connectivity Aware Routing (ECAR) protocol for Vehicular Ad hoc Network (VANET). The protocol uses a control broadcast to reduce the number of overhead packets needed in a route discovery process. It is also equipped with an alternative backup route that is used whenever a primary path to destination failed, which highly reduces the frequent launching and re-launching of the route discovery process that waste useful bandwidth and unnecessarily prolonging the average packet delay. NS2 simulation results show that the performance of ECAR protocol outperformed the original Connectivity Aware Routing (CAR) protocol by reducing the average packet delay by 28%, control overheads by 27% and increased the packet delivery ratio by 22%.

Keywords: Alternative path, primary path, protocol, routing, VANET, vehicular ad hoc networks

INTRODUCTION

Vehicular Ad hoc Network (VANET) is a self organized and self maintained communication network that is formed by moving vehicles to provide safety, entertainment and information to its users. To tap these benefits, efficient and reliable routing protocols are needed. Designing routing protocol in VANET is challenging due to high vehicles' mobility that result in frequent network disconnections. In order to tackle this challenge, numerous routing protocols have been proposed in the literature. The most promising among these protocols are real time connectivity aware protocols. These protocols have the ability to reactively discover connected paths to destination by flooding the networks with a route request message and computing dynamically vehicles' density from an on the fly data collected to enable paths selection. Even though flooding will introduce bandwidth wastage, it is necessary since location service is not assumed. Once a path is selected, it is used for subsequent message transfer between source and destination nodes. The selected path can probably be disconnected over time as the result of change in vehicle density. Since network disconnection is frequent in VANET, remedial measures are necessary. One remedy suggested by ACAR (Yang *et al*., 2010) and AGP (Yan *et al*., 2011) protocols is simply to keep and carry the packet until there exists available next hop. This strategy will work fine if the path disconnection is for a short while. If the disconnection is long or even permanent, this remedy strategy will either prolong the packet delivery time or at worst cause the packet to be lost. Furthermore, since there is no feedback mechanism to the source, the source will continue sending packets through the broken route path which will result in losing all the packets hence decreasing the packet delivery ratio.

Another alternative solution suggested by CAR (Naumov and Gross, 2007) and RBVT-R (Nzouonta *et al*., 2009) protocols is to keep and carry the packet for a threshold time. The RBVT-R (Nzouonta *et al*., 2009) protocol requires that when the time elapsed, the node that detects the problem drops the packet and send a route error message to the source (sender). On receiving of the error message, the source stops sending packets through the broken route path and launches a new path discovery process. In the other hand, the CAR protocol requires that the node that detected the problem to sends an error message to the source node and at the same time begins a search of a new connected path to destination. If the search is successful, the found path is concatenated with the part of the old path to make a new path. This new path is communicated to the source node. The source node analyzes the new path and if it found the path okay it utilize it in subsequent transmission otherwise it launch a new path discovery process. This solution provided by the CAR (Naumov and Gross, 2007) protocol may introduce more control overhead as a consequence of starting new path discovery by the node that detected the route failure or introduces even more control overhead by re-launching a new path discovery by the source node. Analyzing this CAR recovery strategy, it can be seen that any new path discovery has high potential of wasting the network bandwidth in addition to prolonging the delivery time.

Corresponding Author: Ahmadu Maidorawa, Faculty of Computing, Universiti Teknologi Malaysia, 81310, UTM Johor Bahru, Johor Darul Ta'azim, Malaysia

A vehicle equipped with wireless receiver and transceiver can participate freely in the VANET network. Each vehicle is considered as a node and its role can be described as either a host (source or destination) or a router for any given communication in the network. An end to end communication through a large distance is only possible through multi-hop of nodes due to limited wireless communication range of each vehicle. Sometimes permanent nodes are used as roadside units that serve as drop points for messages in sparsely populated roads (Mershad *et al*., 2012) or as a gateway to the global network, the Internet (Mohandas *et al*., 2008).

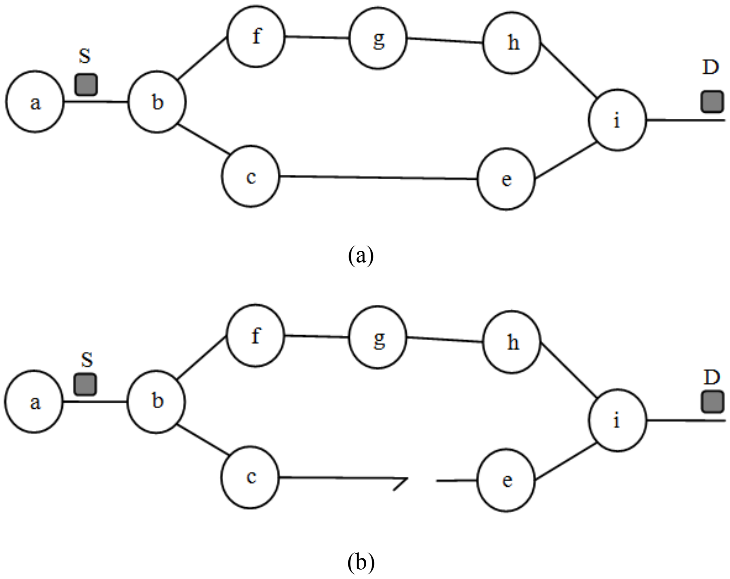
There are numerous VANET applications. The central ideas of these applications are to provide safety, information and infotainment to its users. Safety applications help prevent accidents by providing accident avoidance warnings (Bernsen and Manivannan, 2009).

The earlier attempts to get the VANET routing protocols was to adopt the routing protocols developed for MANET such as Dynamic Source Routing, DSR (Johnson and Maltz, 1996), Ad Hoc On-demand Distance Vector, AODV (Perkins and Royer, 1999) and Greedy Perimeter Stateless Routing, GPSR (Karp and Kung, 2000). These MANET protocols were found to be quite unsuitable for VANET routing because they are adversely affected by the high nodes mobility and signal obstructions like buildings (Naumov *et al*., 2006).

A seminal VANET routing algorithm, Geographic Source Routing (GSR) was proposed (Lochert *et al*., 2003). It uses a static street map of urban city to route packet from source to destination by forwarding packets along the street. Sequences of intersections to be traversed in order to reach a destination are stored in the packet header. The approach can help overcome the problem of signal obstructions that are frequent in VANET but it has little chance of delivering a packet to its destination because it has not considered current vehicle density. This means that, if there is sufficient vehicles availability on the selected route path, the packet can be delivered to its destination otherwise not.

Anchor-based Street and Traffic Aware Routing, A-STAR (Seet *et al*., 2004) utilizes bus route information as a strategy to find routes with a high probability of delivering. Similar to GSR, A-STAR uses a static street map to route packet around signal obstacles. One can easily see that A-STAR is a bit better than GSR as it tries to estimate traffic density of a street based on bus route information but it is not optimal as using dynamic approach that can explores latest traffic condition information. Furthermore, it is probable that a packet can be received by a node that has no neighbors nearer than itself.

Spatial and Traffic Aware, STAR (Giudici and Pagani, 2005) was among the first routing protocol that considered using dynamic traffic density in selecting a routing path. The STAR tries to overcome the problem of sending packet along the street where vehicles may be currently unavailable by exploiting real topology information gathered by network nodes. Two major drawbacks of STAR algorithm are network overheads and its recovery strategy. The algorithm's reliance on traditional beacons may introduce scalability and wasted bandwidth problems since there no heuristic for adapting the beacon to conditions such as high node density. Secondly, in case of routing failure, the node at



(a)

(b)

Fig. 1: Connected path (s) from source to destination

which the failure occurs re-computes the path to destination as there is no backup route to destination in the packet header. This will likely increase the delay time.

Besides the VANET protocols discussed in the previous paragraphs, there are many other routing protocols proposed in the literature. In order to explain and highlight some of their weaknesses, consider Fig. 1. A vehicle node S wants to send message to a destination vehicle node D. Road intersections, also called Anchor Points (APs for short) are represented with letters such as a, b, c, etc. A connected edge say bf means there are sufficient vehicles' availability to multi hop message between the two anchor points b and f.

Connectivity Aware Routing, CAR (Naumov and Gross, 2007) is a routing protocol that finds connected path to destination dynamically. Unlike most of routing protocols that rely on location service to find the position of destination, CAR locates the position of destination by the use of control broadcast called PGB mechanism that minimizes network overheads. Suppose that S wants to send a message to D (Fig. 1a). CAR algorithm will initiate a destination location and path discovery by broadcasting a propagating REQ packet. Each node that receives the REQ packet updates connectivity information (number of hops, average number of neighbors and minimum number of neighbors) on the packet. It also adds an anchor point to path's field in the REQ header if the angle between its velocity vector and that of a sender is above a threshold value. This process is repeated until the REQ reaches the destination D. The node D chooses the path (between (b, c, e, i) and (b, f, g, h, i)) that provides better connectivity and lower delay. Assumed that the path (b, c, e, i) is the better route, D writes this path in reverse order to a response RES packet's header. Eventually RES reply is sent to S using unicast transmission. The node S and D will continue to use this path (b, c, e, i) to exchange messages.

Suppose after some time, the link between c and g is down (Fig. 1b) as a result of non-vehicle availability. The path maintenance of CAR requires the node that detects the problem to take a remedy. The remedy is to keep and carry the packet for a threshold time as disconnections may likely be a temporary one. After the threshold time elapsed, the node that detected the problem initiates a route discovery to D. If it cannot find route to D, it drops the packet and send error ERR message to S. On receiving the ERR message; S starts a new path discovery.

This approach will introduce additional control overhead that causes bandwidth wastage and increase packet delivery delay as there is no useful data transmission during the path discovery process. The problem would have been reduced if S has an alternative backup route to D.

Yang *et al*. (2010) proposed Adaptive Connectivity Aware Routing (ACAR) protocol that is based on statistical and real time density data gathered from an on the fly density collection process. In order to avoid flooding the network to discover a connected path to destination D, statistical density data is used to initially select a route to destination. As packets move from source S to destination D, an on the fly density information is collected. At the destination D, statistical density is compared with the real density collected. If there is significant discrepancy (say 30% difference or more) between the statistical and real density then the destination D notifies the source S to select another route else the same route will be used for subsequent data packet transmission.

Now suppose that S wants to send a message to D (Fig. 1a). S uses location service to obtain the location of D. It then obtains route to D based on statistical density from a Geographic Information System (GIS). Suppose also that the statistical density information of the path (b, c, e, i) is better than that of the path (b, f, g, h, i). ACAR will chooses (b, c, e, i) to send a message to D. At D real traffic density collected will be compared with statistical density. If there is no significant discrepancy between the two traffic densities, ACAR will continue to use the path (b, c, e, i) for subsequent transmission.

Now let us look at what will happen after a situation in Fig. 1b happened. This situation can occur as a result of change in vehicle availability. To remedy the situation, ACAR suggests that the vehicle that detects this problem to keep and carry the packets until there exists available next hop. This remedy will work fine for short time disconnection. If the disconnection is of a long or permanent time, it will result in a long packet delivery delay or even packet lost. Since there is no feedback mechanism to S when a packet is enqueued or dropped, S will continue to send packets through the broken route path which will result in losing all the packets or prolonging the packet delivery time.

Anchor Geographical based routing Protocol, AGP was proposed by Yan *et al.* (2011). Similar to the CAR (Naumov and Gross, 2007) protocol, S gets connected paths to destination D by reactive broadcast. Unlike CAR that identifies Anchor Points (APs) by the magnitude of angle between two velocity vectors, AGP extract APs from the digital map layout. At the destination D, the best path (between (b, c, e, i) and (b, f, g, h, i)) that provides better connectivity and lower delay is chosen. Assumed that the path (b, c, e, i) is the better route, D writes this path in the reversed order to a response, RES, packet's header. Eventually RES reply is unicast to S. The node S and D will continue to use this path (b, c, e, i) to exchange messages by unicast transmission. Suppose after some time, situation in Fig. 1b occurs. The remedy assumed by AGP is just the

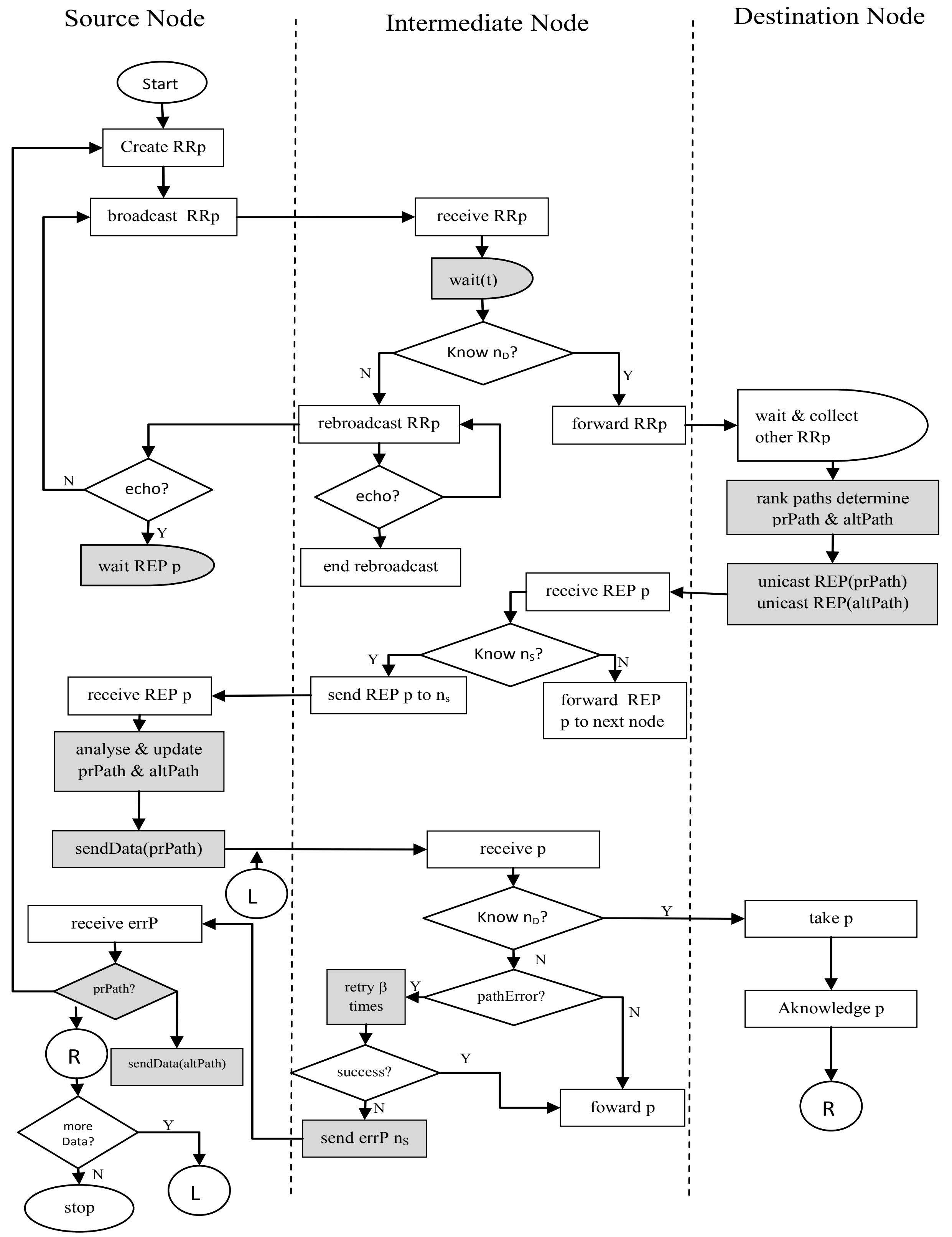


Fig. 2: ECAR protocol algorithm design
▨ : Research contribution; □ : From original CAR protocol; n_S and n_D: Identification address of source and destination, respectively; prPath, altPath: Primary and alternative paths, respectively; p, RRp, REP: Packet, route request packet and Route reply packet, respectively; n_i, n_j: Current node and previous node, respectively

traditional carry and forward strategy. This will prolong the delivery time or most likely cause the packet to be lost. As there is no feedback mechanism to S when disconnection is detected in AGP, S will continue sending packets through the path (b, c, e, i) which all will be lost. This will highly decrease the packet delivery ratio and increases the packet lost ratio.

Road Based using Vehicular Traffic-Reactive, RBVT-R (Nzouonta *et al*., 2009) protocol is very similar to CAR (Naumov and Gross, 2007) in terms of how it discovers routes from S to D and how messages are sent between S and D. When a route error occurs (as in Fig. 1b), the node that detects the problem unicast a route error packet to S. Upon receiving the route error packet, S puts packets for the respective failed route on hold for a threshold timeout. After a timeout it tries to send the packets via the broken route hoping that the disconnection was temporary. S launch new route discovery after few consecutive route errors. The consequence of this remedial measure is that re-attempting to use the broken link will likely increase delivery delay and launching new discovery will cause additional control overheads that cause bandwidth wastage and increase the packet delivery delay. The problem will have been reduced if S has a backup route to D.

Therefore, this article enhances a Connectivity Aware Routing, CAR (Naumov and Gross, 2007) protocol to provide better performance. The resulting new protocol called an Enhanced Connectivity Aware (ECAR) protocol, reduces the network control overhead by using a control broadcast and also reduces the need for re-launching of a new path discovery process whenever a connected path breaks by utilizing an alternative backup route.

MATERIALS AND METHODS

The proposed ECAR protocol consists of two major changes to the CAR protocol. The first change was in the route discovery process while the second was in the route maintenance handling. The route discovery was modified to use control broadcast during the route request and the route reply to include an alternative backup path between the source and the destination nodes in addition to the primary path. The route maintenance mechanism was modified so that whenever a route failure occurred, the source node uses the alternative backup route for transmission of data and when the alternative route itself failed then the new path discovery is launched. Figure 2 depicts a diagrammatic representation of ECAR protocol. The colored shaped denote the areas of research contribution while the un-colored shapes are from the original CAR protocol.

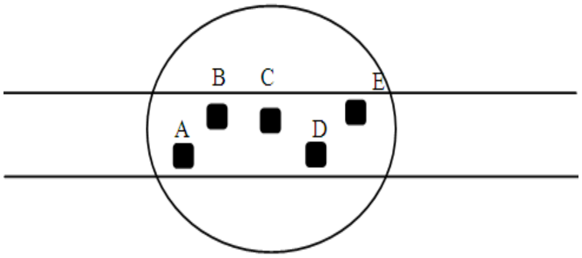


Fig. 3: Illustration of control broadcast

Control broadcast waiting time: For brevity of explanation, consider Fig. 3 where a vehicle node C at the center broadcast a route request packet. All the neighboring vehicles within its radio communication range will receive the broadcast packet. Without a control broadcast all vehicles that received the packets rebroadcast them further. With a control broadcast, only vehicles A and E rebroadcast the request packet further.

The waiting time wait (t) of a neighboring node that receive route request broadcast is derived from the inverse proportion as:

$$wait(t) \propto \frac{1}{d} \quad (1)$$

where,
d : The distance between the sender and receiver

Thus:

$$wait(t) = \beta\frac{1}{d} \quad (2)$$

where, β is the constant of proportionality. Now the concern is to determine the value of β. To get β, it is sufficient to do some analysis on radio waves.

One megahertz of radio signal has a wavelength of 299.8 m (Wikipedia, 2013). Hence 1 GHz will have a wavelength of 0.2998 m. In Naumov *et al*. (2006) radio frequency was modeled at 2.4 GHz. Using this frequency of 2.4 GHz, the corresponding wavelength is 0.124917 m, which equivalent to say 2.4 MHz has a wavelength of 124.917 m. This means that every $\frac{2.4}{10^6}$ sec, the signal covers 124.917 m. Using *R* meters radio communication range, β is set to the time a signal will take to cover distance *R* and it is calculated as follows:

$$\beta = \frac{2.4}{10^6} \times \frac{R}{124.917} = \frac{1.9213R}{10^8} \quad (3)$$

Substituting Eq. (3) in (2), the waiting time becomes:

$$wait(t) = \frac{1.9213R}{d \times 10^8} \quad (4)$$

Thus, Eq. (4) provides the waiting time used in the control broadcast. As mention before d is the distance between the broadcast sender and receiver and R is the signal radio communication range.

Route discovery process: To find a route to a destination node, ECAR uses control broadcast in addition to Preferred Group Broadcast (PGB). The PGB eliminates redundant retransmission of route request packet so that whenever a particular node broadcasts route request packet, it starts listening, if it is echoed further then it stops the rebroadcast otherwise it repeats the packet broadcast after waiting for a set time interval (Naumov *et al*., 2006).

In the other hand, the control broadcast helps to reduce the bandwidth wastage incurred as a result of route discovery. Any intermediate node that is not the destination that receives a route request packet, it is forced to wait for a time that inversely proportional to the distance between it and the immediate node that forwarded the route request packet. This will allow the farthest node that receives the route request packet to broadcast it further before the closer nodes. This is because the farthest node will have a shorter waiting time due to the inverse proportionality than the closer ones. Any node that receives an echo of the route request packet it hold within its waiting time, it stops the re-broadcasting since a further node has already rebroadcasted the packet.

Any intermediate node that receives a route request packet, it adds its *id* into the receive path discovery table to avoid routing loop. It also updates the routing information fields in the packet header. The number of hops is incremented by one. The average number of neighbors is updated as follows:

$$avrNeighbor = \frac{avrNeighbor \times (hopCount - 1)}{hopCount} \quad (5)$$

If the number of neighbors of the current nodes is less than the minimum number of neighbors, the minimum neighbor field in the packet header is set to the number of neighbors of the current node.

An anchor point (intersection) is identified when the angle between two velocity vectors is greater than 18° as in Naumov *et al*. (2006). A new anchor point is added to a broadcast packet anytime the request packet passes a new intersection.

When the request packet finally reaches the destination, the destination node will have a complete sequence of anchor points that need to be traversed to reach back the source. After receiving the first route request, the destination waits a while to collect other routes that follow different paths. These paths are sorted or ranked in decreasing average neighbor field and then by decreasing minimum neighbor field. The top most path in the rank is chosen as the primary path while the second top most path in the rank is made the alternative backup path. The destination prepares two reply packets (one for the primary path and one for the alternative path) and send them to the source using unicast transmission.

When the source node receives a route reply from a destination node for the first time, it stores it as primary path and begin sending data packets using the path. When it receives the second route reply, it compares it to the primary path. If it is better than the primary path, the new path is made the primary path and the old primary path becomes the alternative path otherwise the new path is made to be the alternative backup path.

Data packet transmission: Once a source has connected path or paths to a destination, it starts sending data packets to the destination using unicast transmission through the primary path as default. A path consists of a sequence of intersections called anchor points that need to be traversed to reach the destination. Packets are forwarded greedily to the furthest node towards to the next intersection (anchor point) instead to the furthest node towards the destination. Each intermediate forwarding node checks if the distance between it and the next anchor point is less than half the node's coverage range as in Naumov *et al*. (2006). If so, then this anchor point is marked and the next one is set as the target. This process continues until the destination is reached.

Route error recovery process: Route path disconnection is frequent in VANET and this is usually called route error. It is normally occurs when an intermediate node receives a packet but no any next node closer to the target intersection in which to forward the packet to. ECAR protocol is equipped with a route error recovery process to help overcome route error.

When a route error occurs, ECAR protocol enters route error recovery process. In this process, the node that detects the error starts buffering data packets and probes for the next available node. The probe is performed for a specific number of times. If the probe is successful, the buffered packets are then forwarded to the next available node in the direction of the target intersection. If the probe for the next available node was unsuccessful, the buffered packets are dropped and a route error message is sent to the source. When a source node receives an error packet, it checks whether the broken route path is the primary path. If so, it uses the alternative backup path to send the data packets to the destination. New path discovery will only be launched when both the primary path as well as the alternative backup path failed.

Table 1: Simulation setup

Parameter	Value
Simulator	NS-2.33
Simulation area	1500×1500 m
Simulation time	300 sec
Transmission range	250 m
Antenna type	Omni antenna
MAC type	802.11
Radio propagation model	Two ray ground
Routing protocols	ECAR, CAR
Queue size	50 packets
Packet generation interval	0.25 sec
Packet size	512B
Varying densities:	
Vehicle density:	
Low	10-30
Medium	40-70
High	80-160
No. of TCP connections	10% of vehicle density
Vehicle velocity	40 km/h

Probing broken route for a specific number of times helps to overcome intermittent disconnections which last only for a very short while. Sending error message to the source notified the source that there was a link failure in the route path. The error message serves two purposes. One, the source stops sending packets through the broken route path and secondly, it makes the source to utilize the alternative backup path for subsequent packets transfer.

Neighborhood table management: In this study, a neighborhood table management process of CAR protocol (Naumov and Gross, 2007) was used in the ECAR protocol.

Simulation setup: In this research experiment, the NS-2.33 simulation tool was used as the simulation platform (Issariyaul and Hossain, 2009). The area of simulation was 1500×1500 m. The radio transmission range and MAC type were 250 m and 802.11, respectively. Scaling models used in this experiment were varying vehicle densities. The detail of this setup is displayed in Table 1.

The simulation parameters and their corresponding values are chosen based on previous researches to provide a good basis for the evaluation of ECAR protocol. NS2 was selected as in Naumov *et al.* (2006), Yan *et al.* (2011) and Yang *et al.* (2010) etc. Varying vehicle density as in Naumov *et al.* (2006) and Yan *et al.* (2011). Simulation area as in Nzouonta *et al.* (2009) and Yang *et al.* (2010). MAC type, radio propagation and signal range as in Yang *et al.* (2010) and Yan *et al.* (2011). Simulation duration time as in Naumov *et al.* (2006) and Yang *et al.* (2010).

Evaluation metrics: The metrics for performance comparisons are as follows:

- **Packet delivery ratio:** The fraction of successfully delivered to the destination relative to the total packets sent.
- **Packet lost ratio:** The fraction of lost packets during transmission relative to the total packets sent.
- **Average delay:** The average duration that takes a packet to travel from source to destination.
- **Control overhead:** The absolute number of routing packets necessary to find connected paths and manage neighborhood tables.

These metrics were chosen for performance evaluation of ECAR because they are indicators used by previous researchers in evaluating the performance of routing protocols as can be found in Naumov *et al.* (2006), Yan *et al.* (2011) and Yang *et al.* (2010).

RESULTS AND DISCUSSION

There are four metrics used in the evaluation of ECAR protocol. These metrics are packet delivery ratio, packet lost ratio, average packet delay and control overhead.

Packet delivery ratio: Figure 4 shows the simulation result of low vehicle density. It can be observed that ECAR was able to deliver 5 to 32% of the total packet send while CAR only delivered 4 to 24% of the total packet send. Even though the packet delivery ratio was generally low for both protocols, ECAR gained a performance increase over CAR protocol by 28.8%. Possible reasons for this improvement will be discussed after considering the medium and the low vehicle density.

The performance of both CAR and ECAR in the medium vehicle density was remarkably better than that of the low vehicle density as can be seen in Fig. 5. CAR protocol delivered up to a maximum 66% of the packets send while ECAR continues to give an edge by delivering up to 82% of the total packets send. This gave 29% average performance of ECAR relative to CAR protocol.

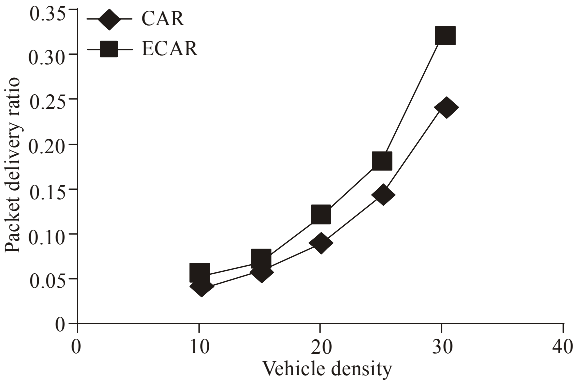


Fig. 4: Packet delivery ratio-low vehicle density

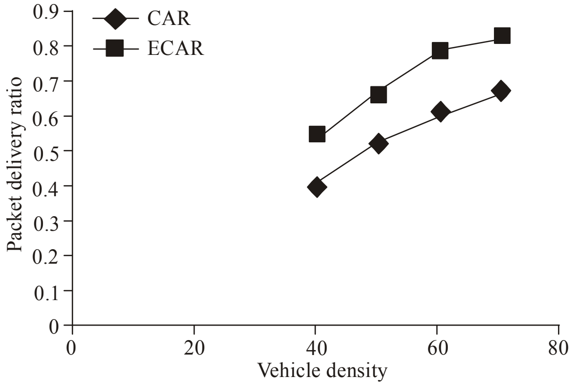


Fig. 5: Packet delivery ratio for medium vehicle density

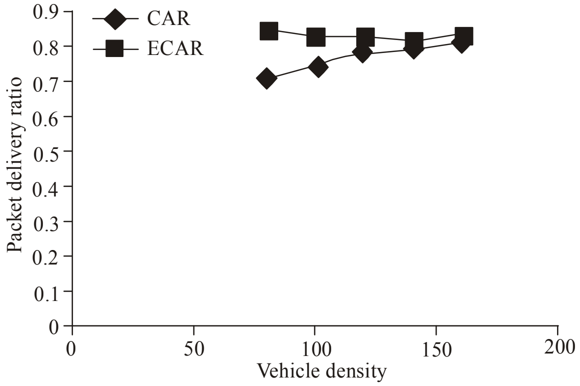


Fig. 6: Packet delivery ratio-high vehicle density

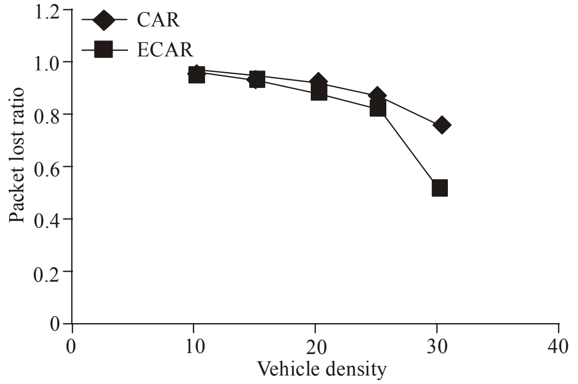


Fig. 7: Packet lost ratio-low vehicle density

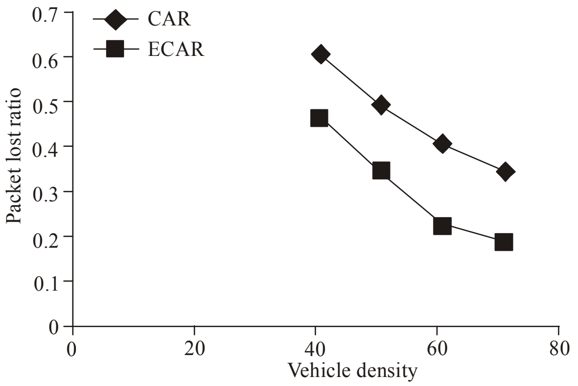


Fig. 8: Packet lost ratio-medium vehicle density

In a high vehicle density, ECAR packets delivery fluctuates between 81 to 84% of the total packets send as shown in Fig. 6. The CAR protocols delivered between 70 to 79% of the packets send. This gave a narrow performance gained of 8% by ECAR protocol.

In all the three vehicle densities-low, medium and high, ECAR protocol performs better than the original CAR protocol. This performance is as a result of ECAR protocol has an alternative backup route to the destination so that anytime the primary route breaks, the node that detects the problem sends an error message to the source. The source, upon receives an error notification uses alternative path to route the packets to its destination. In the other hand, the CAR protocol does not keep alternative route to destination. Therefore, whenever a route to destination breaks, the CAR protocol requires the node that detects the problem to launch a new route discovery after a specific number of trials. During the new path discovery, all the incoming packets are buffered. If the new path search is unsuccessful, the buffered packets are dropped which contribute the lower packet delivery ratio compared to ECAR that utilized alternative backup route.

Packet lost ratio: Packet lost ratio for CAR protocol was generally high in the low vehicle density losing ranging between 96% down to 76% of the total packets send while ECAR protocol was able to reduced the lost by 11.2% relative to the CAR protocol as can be seen in Fig. 7.

At the medium vehicle density, the performance ECAR protocol was remarkable as shown in Fig. 8. ECAR protocol lost 46% down to 18% of the total packets send while CAR protocol lost 60% down to 34% of the total packets send. This yields a performance gained by 60.5% of ECAR relative to CAR protocol.

Figure 9 shows packet lost ratio for the high vehicle density. It can be seen from the Fig. 10 packets lost ratio converged to 20% for both the two protocols under consideration.

In the overall, ECAR protocol brings the packet lost ratio down compared to CAR protocol. This advantage is achieved by utilizing the alternative path by ECAR whenever the primary route path fails. The CAR reliance on re-launching new path discovery by either the intermediate nodes or the source node increases the packet lost ratio. Furthermore, in the high vehicle density it can be observed that the packet lost for the two protocols are almost same. A possible reason for this is that the probability of path disconnection in high vehicle density is generally low

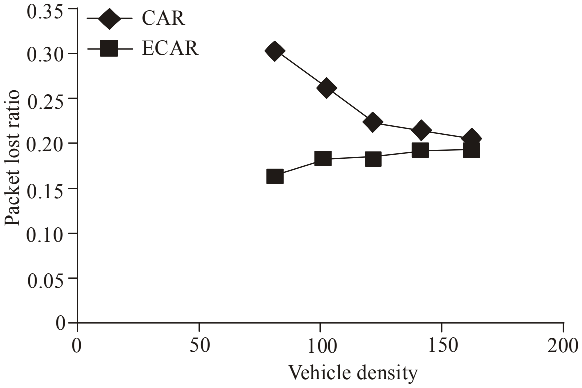


Fig. 9: Packet lost ratio-high vehicle density

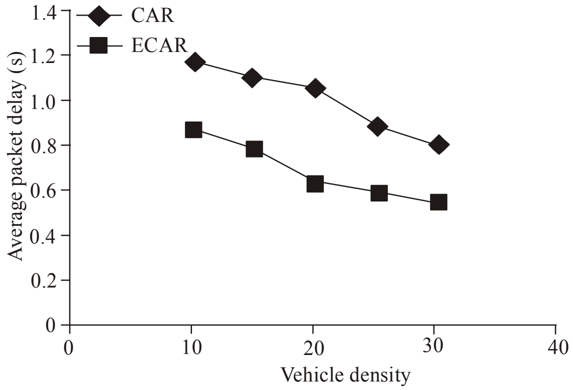


Fig. 10: Packet delivery delay-low vehicle density

as there are sufficient number of vehicles to multi hop data packet to a destination.

Average packet delay: Figure 10 shows the average data packet delay for low vehicle density. For all the two protocols, the packet delay generally reduces with the increases vehicle densities. ECAR protocol outperforms CAR protocol by having an average packet delay of 0.85 sec down to 0.54 sec compared to CAR protocol which has average packet delay of 1.15 sec down to 0.78 sec.

The packet delivery delay in the medium density is shown in Fig. 11. ECAR protocol has an edge of 8.75% over CAR protocol. The highest delay for CAR was 0.6 sec while that of ECAR was 0.53 sec.

The average packet delay slightly dropped from 0.52 sec down to 0.48 sec for CAR and 0.45 sec down to 0.37 sec for ECAR protocol which indicate that ECAR is better than CAR protocol by reducing the delay by 27.8% as shown in Fig. 12.

Analyzing the three groups of vehicle densities it can be observed that ECAR protocol reduces the average packet delay compared with what was obtained with the CAR protocol. The main reason for the higher average packet delay of CAR protocol is because of its usual re-launching of route request by intermediate nodes or by source nodes whenever a route failure occurs. Every re-launching of route request will consume a substantial amount of time that increases the delivery delay. On the other hand, ECAR protocol was able to keep the average packet delay low as it uses an alternative path to destination whenever the primary route path fails.

Routing overheads: Figure 13 shows the routing overheads for both the ECAR and the CAR protocols in

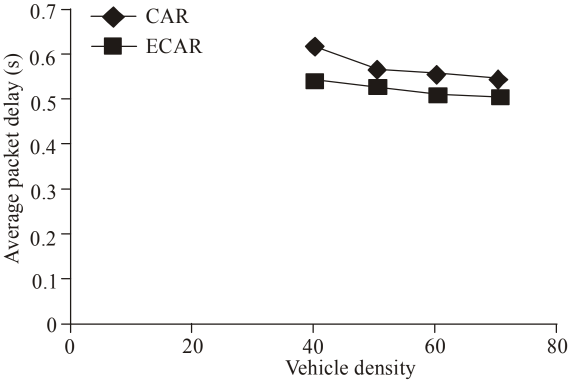


Fig. 11: Packet delivery delay-medium vehicle density

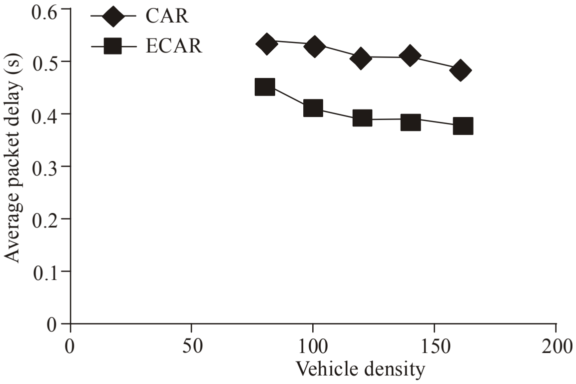


Fig. 12: Packet delivery delay-high vehicle density

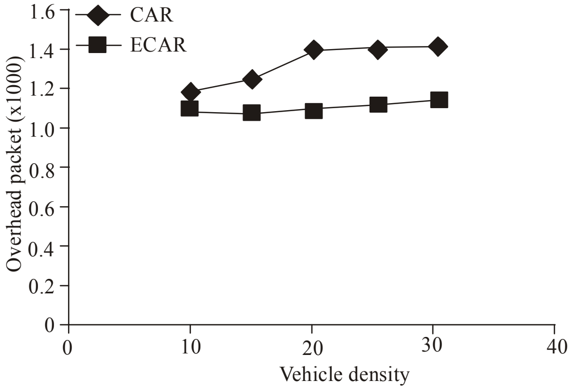


Fig. 13: Routing overhead for low vehicle density

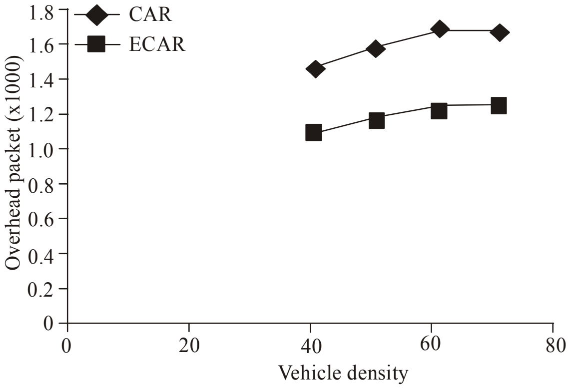


Fig. 14: Routing overhead-medium vehicle density

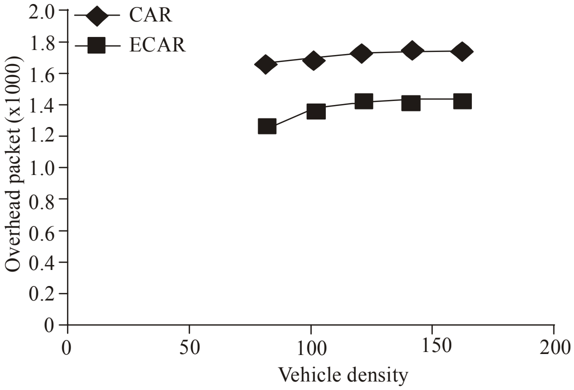


Fig. 15: Routing overhead-high vehicle density

low vehicle densities. The ECAR protocol overhead is less than that of CAR protocol by 20%. Both the two the protocols show slight increase overhead as the vehicle density increases.

In the medium vehicle density, the routing overhead of ECAR was much smaller compared to that of CAR protocol as can be seen in Fig. 14.

ECAR protocol continued to give an edge in reducing the routing overhead even in the high vehicle density as shown in Fig. 15. The possible reason is that ECAR uses control broadcast in addition to the PGB. One important observation is that as the number of vehicle densities continues to rise up, the routing overheads of the two protocols were relatively unchanged. This shows that the two protocols are scalable.

The reduction of control routing overhead packets was achieved in new proposed ECAR protocol due the control broadcast embedded in the route path discovery process. The new protocol requires fewer control overhead since not all the nodes that receives a broadcast packets forward it further, it is only the farthest nodes that do the rebroadcast. Secondly, the first route path discovery is necessary to get connected paths to the destination and subsequent re-launching of a route discovery by the intermediate node or by the source depends on route failure. Since ECAR is equipped with an alternative route to destination to utilize whenever the primary route fails, the number of required route discovery process is highly reduced which automatically yields reduction in the routing control overhead. In the other hand, the original CAR protocol only uses PGB in its broadcast, only the sender of the broadcast packet is restricted but all other receivers are allowed to re-broadcast the route request further creating more control overhead. Since this will be needed in every re-launching of path request during long route failure, more and more control overheads are introduced into the network.

Both CAR and ECAR protocols show steady rise of control overheads as the vehicle density increases in the low and medium densities and flatten to certain values in the high vehicle density as displayed in Fig. 13 to 15. The rise in CAR is due beaconing rate and route discovery packets in route path maintenance. The beaconing rate is high with a low vehicle density and less with sufficient vehicle density and these resulted in the rise and flattening in low and high vehicle density, respectively. The reason for flattening is due to the fact that CAR protocol uses an adaptive beaconing mechanism. Similarly, the route maintenance will also be needed more when the vehicle density is low due frequent path disconnection and it will be required less when the vehicle density is high as route path becomes more stable. On the other hand, even though the corresponding ECAR protocol steady rise and flatten in the low and high vehicle densities, it produces lower overheads compared to the former protocol due its control broadcast and being equipped with alternative route path as discussed in the preceding paragraph. The flattening indicates the scalability of the two protocols.

CONCLUSION

There are two major contributions of this research that greatly help to enhance the performance Connectivity Aware Routing protocol. First, in the path discovery process, a control broadcast was introduced. The second contribution was introduction of an alternative backup path to be used in addition to the primary path. The alternative backup path is used by the endpoint nodes (source or destination) whenever the primary path fails.

In particular, future research should consider extending the use of the alternative backup route to anchor points instead of restricting to only endpoint. In general, feature researches should target security and privacy issues in order to make the VANET technology deployment acceptable to users. This is because most of current researches on VANET routing protocols assume that vehicles freely communicate with each other without giving due consideration for security and privacy issues. If security issues are not addressed squarely, some people can exploit this vulnerability and cause harm to its users.

REFERENCES

Bernsen, J. and D. Manivannan, 2009. Unicast routing protocols for vehicular ad hoc networks: A critical comparison and classification. Perv. Mob. Comput., 5(1): 1-18.

Giudici, F. and E. Pagani, 2005. Spatial and Traffic-Aware Routing (STAR) for vehicular systems. Lect. Notes Comput. Sc., 3726: 77-86.

Issariyaul, T. and E. Hossain, 2009. Introduction to network simulator NS2. Springer, New York, pp: 1-400.

Johnson, D. and D. Maltz, 1996. Dynamic source routing in ad hoc wireless networks. In: Imielinski, T. and H. Korth (Eds.), Mobile Computing. Kluwer Academic, Dordrecht, the Netherlands, 353: 153-181.

Karp, B. and H.T. Kung, 2000. GPSR: Greedy perimeter stateless routing for wireless networks. Proceeding of the 6th Annual International Conference on Mobile Computing and Networking (MobiCom 2000). New York, USA, pp: 243-254.

Lochert, C., H. Hartenstein, J. Tian, H. Füÿler, D. Hermann and M. Mauve, 2003. A routing strategy for vehicular ad hoc networks in city environments. Proceedings of the IEEE Intelligent Vehicles Symposium, pp: 156-161.

Mershad, K., H. Artail and M. Gerla, 2012. ROAMER: Roadside units as message routers in VANETs. Ad Hoc Netw., 10: 479-496.

Mohandas, B.K., A. Nayak, K. Naik and N. Goe, 2008. ABSRP-a service discovery approach for vehicular ad-hoc networks. Proceedings of the 3rd IEEE Asia-Pacific Services Computing Conference. Pisa, Italy.

Naumov, V. and T. Gross, 2007. Connectivity-Aware Routing (CAR) in vehicular ad-hoc networks. Proceeding of the 26th IEEE International Conference on Computer Communications (INFOCOM 2007), Anchorage, AK, pp: 1919-1927.

Naumov, V., R. Baumann and T. Gross, 2006. An Evaluation of Inter-Vehicle Ad Hoc Networks Based on Realistic Vehicular Traces. Proceeding of the 7th ACM International Symposium on Mobile Ad Hoc Networking and Computing (MobiHoc, 2006), pp: 108-119.

Nzouonta, J., N. Rajgure and G. Wang, 2009. Vanet routing on city roads using real-time vehicular traffic information. IEEE T. Veh. Technol., 58(7): 3609-3625.

Perkins, C. and E. Royer, 1999. Ad-hoc on-demand distance vector routing. Proceeding of the 2nd IEEE Workshop on Mobile Computing Systems and Applications (WMCSA, 1999), pp: 90-100.

Seet, B.C., G. Liu, B.S. Lee, C.H. Foh, K.J. Wong and K.K. Lee, 2004. A-STAR: A mobile ad hoc routing strategy for metropolis vehicular communications. Proceeding of the 3rd International IFIP-TC6 Networking Conference on Networking Technologies, Services and Protocols; Performance of Computer and Communication Networks; Mobile and Wireless Communications, Springer, Berlin, Heidelberg, 3042: 989-999.

Wikipedia, 2013. Radio Waves-speed, Wavelength and Frequency. Retrieved from: https://en.wikipedia.org/ wiki/ Radio_waves.

Yan, S., J. Xiao-Ye and C. Shan-Zhi, 2011. AGP: An anchor-geography based routing protocol with mobility prediction for VANET in city scenarios. J. China Univ., Posts Telecommun., 18(Suppl. 1): 112-117.

Yang, Q., A. Lim, S. Li, J. Fang and P. Agrawal, 2010. ACAR: Adaptive connectivity aware routing for vehicular ad hoc networks in city scenarios. Mobile Netw. Appl., 15(1): 36-59.