A Registration System for Aiding in Localization and Routing in Hybrid VANETs

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Abstract—**Hybrid vehicular ad hoc networks (VANETs) allow Inter-Vehicle Communications and Roadside-to-Vehicle Communications. The proposed protocol utilizes the Roadside Units (RSUs) for the implementation of a registration process which allows for the provision of a localization service. The presented RSUs architecture breaks the VANETs into smaller regions managed by a RSU in which individual On Board Units (OBUs) register providing its current position and velocity vectors. Using the data provided by the OBUs, a localization service can be implemented. When the source need to send data, the location of the destination is calculated at the source RSU and the destination RSU using controlled flooding locates the destination vehicle and establishes a route path between source and destination. Simulation results show that it performs well providing good throughput, high packet delivery ration, low delivery delays with very low overhead.**

Keywords- Hybrid VANETs; roadside units; localization service

I. INTRODUCTION

The importance of safety and comfort on vehicles has allowed the advancement of Vehicular Ad-hoc Networks (VANETs). VANETs are mainly designed for the transmission of safety applications in an Inter-Vehicle Communication (IVC) Network, but it has also expanded for the incorporation of infotainment applications and the integration of Roadside-to-Vehicle Communication (RVC). Inter-Vehicle Communication is supported by On Board Units (OBUs) which provides the interface for wireless communications among vehicles. Roadside Units (RSUs) provide the wireless interaction for the support of Roadside-to-Vehicle communications.

Routing of data in VANETs has presented itself as a major challenge, and many protocols have been designed to improve routing. Many of these protocols as seen in [1-5] are routing protocols based on the assumption that the destination's location is known. Such protocols start to find either the shortest route to the destination or with predictions of traffic conditions and road layouts try to find stable route paths between source and destination. In [6], the protocol provides mechanisms to search for the destination before it establishes routes from source to destination. Although it performs well in maintaining a stable route, its drawback is in locating the destination. It requires broadcasting the VANETs which may cause excessive flooding and inefficient use of bandwidth utilization, thus making it inadequate as a location service.

Many protocols have been presented specific for VANETs such as GPCR in [7]. GPCR is presented as a protocol that applies geographic routing to discover a path from source to destination. However, it does not consider other data pertaining to VANETs such as road densities or map information; it sees the street layouts as a graph where the packet has to traverse. It uses road junctions as the determining factor for forwarding decisions depending on nodes at the junction avoiding the local optimum problem. SAR [8] similar to [2] also utilizes map streets although it provides mechanisms to deal with how the packet knows about a junction and also how to handle cases when there is no node to forward the packet, such as re-computing the path. The aforementioned protocols present drawbacks such as the inability to locate the destination vehicle before initializing the routing of data thus depending on a localization service.

Protocols that provide routes based on traffic information such as traffic densities are VADD [1], A-STAR [9], MDDV [10], and SADV [11]. These protocols take into consideration the density of streets, when routing information. A road with higher density is chosen instead of a lower density road even if the lower density road provides the shortest route. A drawback of these protocols is that to use real time data about traffic conditions incurs a complexity on the computational analysis to produce accurate results on traffic conditions thus the complexity on the computations is a trade-off on the accuracy of the protocols.

Broadcasting [12] in VANETs for vehicle localization is not a feasible option since this produces a high number of collisions and reduces throughput. Geographic routing [13] greatly reduces unnecessary broadcasting and limits the region to search for the destination's location. By taking advantage of hybrid VANETs, the protocols [14][15][16] makes use of RSUs to provide assistance in providing the destination's location and providing a routing path between source and destination. Roads are divided into sectors where one or multiple RSUs are responsible for a particular sector; vehicles affiliate to an RSU depending on the sector it is currently travelling. The RSUs also act as an intermediary in the route paths for connecting source and destination that are located on different sectors. Although these schemes greatly reduce the broadcast and localization problem, the constant affiliations from RSU to RSU poses a drawback in that it incurs an overhead and the constant change of the routing path in changing RSU at a regular basis.

Hybrid VANETs provide an opportunity for the development of a location service and a routing protocol. By taking advantage of the infrastructure provided by RSUs to act as the networks backbone, information can be easily distributed throughout the VANETs. As a result, a location service based on a registration system for all vehicles is presented. A city is divided into regions; each region is managed by a RSU. This requires a one-time registration for a region instead of multiple affiliations within a segment of a road. The OBUs send information such as velocity vectors, trajectory vectors, timestamp, GPS coordinates and Vehicle ID. With this information the RSU can locate the position of destination vehicles. Also, with the assistance of RSUs, a route can be established and the destination vehicles can be located faster with fewer resources. A good performance on the delivery ratio and throughput is reached using this architecture. The presented protocol responses well on high number of vehicles in the VANETs and the localization service allows for better controlled flooding of the VANETs for locating the destination lowering the overhead and increasing the throughput.

The remainder of this paper is organized as follows. Section II provides a detail explanation on the framework for the registration process and a description on the routing protocol implementation. Section III shows the performance of the protocol through simulations. Finally, Section IV concludes this paper.

II. THE PROPOSED PROTOCOL: REGISTRATION SYTEM AND LOCALIZATION SERVICE

The details of the RSUs Architecture, the registration process of vehicles on the RSU network, and the localization service is discussed in this Section. It is assumed that all vehicles are equipped with a Global Positioning System and the GPS system provides digitized maps of street layouts. Vehicles are equipped with OBUs. These OBUs and the RSUs use dedicated short range communication (DSRC) defined as IEEE 802.11(p) as the medium for communication transmissions.

A. RSUs Network Architecture

Hybrid VANETs support the interconnection of RSUs and vehicles, these RSUs are interconnected via links that support high bandwidths and low latency which provide the infrastructure for a stable and reliable backbone network for the VANETs. This interconnection can be supported by fiber optics providing a RSU mesh network. The RSU units would be geographically distributed over a city and located on strategic positions such as at major road intersections or main roads. The RSUs network allows for the partition of the VANET into regions which can be managed by an individual RSU.

Each RSU would be responsible for managing the registration process of vehicles, providing the location information of vehicles, and creating the route from itself to the desired vehicle within its region. The wireless transmission range of each RUS is within 250 to 300 meters enough to cover a road's width. A RSU region is defined as covering approximately 1 km^2 of a city's area. Each region is enclosed by a set of static coordinates, which denote the region area in which a particular RSU is responsible for monitoring; the enclosed area within the static coordinates will be known as the RSU coverage area as shown in Fig. 1. Also there is a handoff area between regions. These handoff areas are for the smooth transition of handling control of vehicles movement between RSU's regions to avoid the Ping-Pong effect.

B. Vehicle Registration Process

All vehicles are required to register to the VANET. The first phase of the registration process is that each RSU advertises its RSU ID, its position and the coordinates of its coverage area. Vehicles receive the RSU's information, accept the RSU affiliation, and register to that RSU by sending its corresponding vehicle ID, velocity vectors, trajectory vectors, and GPS coordinates. The communication among RSU and OBU in this phase is of a single hop connection. The RSU captures the vehicle's data and stores the data in a database attaching its RSU ID to that record. The database is accessed via the RSUs network thus making the data accessible by all the RSUs.

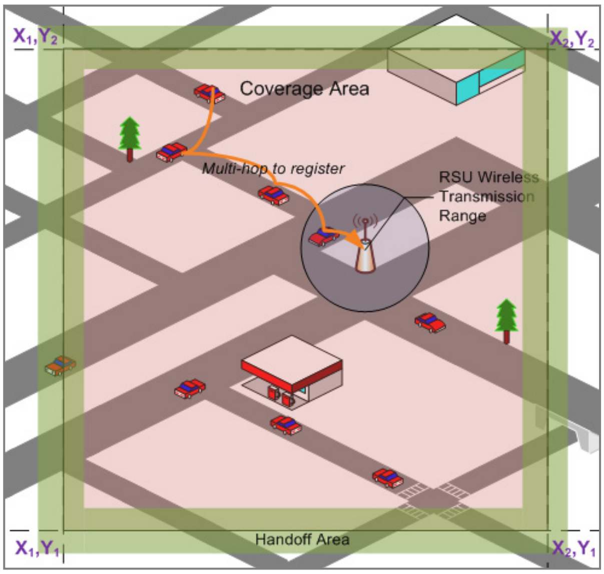


Figure 1. RSUs Network Architecture: RSUs Coverage Area and Handoff Area

The second phase is to propagate the RSUs information throughout the coverage area and to register vehicles within this area. Vehicles which are already registered in the system and move within its corresponding RSU region, broadcast the RSU information to its one hop neighbor with TTL=4 until TTL=0. Vehicles that are not yet registered to a RSU and encounter one of the transmitted RSU information packets, it verifies the RSU coordinates against its GPS coordinates in which it resides. After the verification, it confirms that it is within that RSU coverage area. The vehicle forwards the RSU its OBU ID and the rest of data. The OBU sends it data using a routing protocol like GPSR [17] towards the RSU. This process ensures that all vehicles are registered to an RSU for localization and routing purposes. Vehicles will register on the VANETs only once when the OBU is entering the VANETs and update its information only when the OBU has traversed to consecutive RSU regions.

C. Location Service

The registration process guarantees that all vehicles are affiliated to one RSU. While locating a vehicle, there are three possible scenarios 1) the destination vehicle is not on the VANET, 2) the destination vehicle is located closer to the source than an RSU, and 3) the destination vehicle is located closer to an RSU than to the source, shown in Fig. 2. For the three possible scenarios, when the source node wants a route to send data to a destination node, it first sends a Destination Request (DREQ) message to its corresponding RSU. Packets from source to an RSU are via a unicast connection supported by a routing protocol like GPSR. The DREQ includes current trajectory and velocity vectors and GPS coordinates of source vehicle along with the vehicle's ID of the intended destination. When receiving the DREQ, the RSU updates the information of the source node and accesses the database on the RSU network and locates the data corresponding to the destination node. For the first possible scenario where the vehicle is not registered on the VANET, the RSU would not find a match for the intended destination and replies to the source with a Destination Error (DERR) message. If the vehicle is identified as being present in the VANET, either scenario (2) or (3) is implemented. For either scenario the RSU calculates the destination's location from the velocity vectors, trajectory vectors, and GPS coordinates registered on the RSU network.

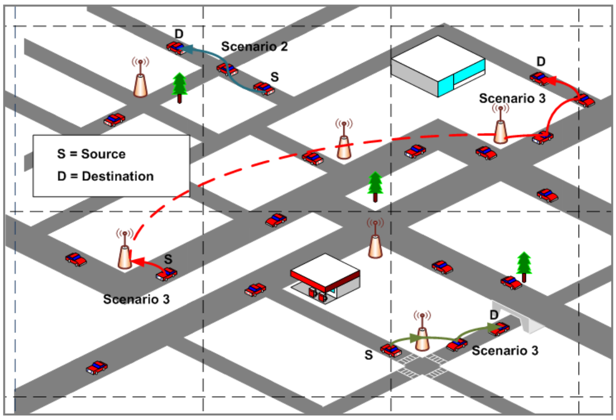


Figure 2. Three different scenarios for the localization service

Scenario (2) states that the destination is closer to the source than to an RSU, then the RSU replies with a Destination Found (DESF) message along with the calculated destination's location. The source is then responsible to do a controlled flooding towards the expected location of the destination with a Route Request (RREQ) with TTL = 6. The RREQ can be broadcasted to another RSU region. The Route Request appends the traversed path towards the destination in its packet header. When the destination receives the first RREQ which has the minimum delay time, it replies to the source with a Route Reply (RREP) message via the path appended on the RREQ. As the source receives the RREP, it then initiates packet forwarding to the destination on the established communication path using a routing protocol like GPSR.

For scenario (3), just as the previous scenario, the source sends a Destination Request (DREQ) to the source RSU. The RSU updates the source information on the database, verifies whether the destination vehicle is registered on the system, and calculates the location of the destination. From the calculations, the destination location is found that it is closer to a RSU. Then the corresponding RSU responsible for the region where the destination is predicted to be located is responsible for doing a control flooding on the VANET with the Route Request (RREQ) with TTL = 6 towards the calculated area of the destination's location. The TTL = 6 is such that the RREQ message can cover the corresponding RSU's region and also the neighboring RSUs regions. The RREQ message appends the traversed trajectory to the destination. As receiving a RREQ, the destination vehicle sends a Route Reply (RREP) message to the RSU via the path the RREQ traversed. The RSU on receiving the RREP sends a Destination Found (DESF) message to the source and the source starts to send the data to the RSU. The RSU receives the packets from the source and for forwards the packets to the destination via the found route. The communication from source to destination is established as follows: source vehicle to source RSU to destination RSU to destination vehicle. If the route path is broken from destination RSU to destination node, packets from the source are buffered at the destination RSU, until a new path is found.

D. *Handoff Procedure*

The mobility within the VANETs causes the OBUs to constantly trespass into other RSU regions. Handoffs are considered on two scenarios. One of the scenarios includes when OBUs move from one RSU region to another RSU region. Vehicles that move from its registered region to another RSU region do not immediately register to the new RSU. The OBU will only re-register to a new RSU after traversing two consecutive RSUs regions; this avoids the constant registration of the vehicle and avoiding increasing the network data traffic.

Handoffs are also considered during routing, where the routing path is from source to RSU and RSU to destination. In this scenario there exists the possibility that either node moves from one region to another region as the routing is in session; therefore, the node moving to a new RSU region requests an update in its routing path. These handoffs are initiated by the node which has moved to a new RSU region. From the registration process the RSU information is propagated within its region, thus a node that has moved to a new RSU region can overhear this information. The node on detecting it has moved to a new RSU region and overhears the RSU information pertaining to the new RSU region sends a Route Request (RREQ) to the new RSU. If a route path can be established from the RSU to the OBU a handoff is performed from the old RSU to the new RSU and the routing path is updated; otherwise the ongoing routing path from the original RSU to the OBU is kept.

III. SIMULATION ANALYSIS

In this Section, the simulation environment and the results with different metrics are presented. The proposed protocol is evaluated under urban conditions.

A. *Simulation Environment and Metrics*

To evaluate the performance of the registration system and the location service of the presented protocol, several simulations were conducted using the NCTUns Network Simulator and Emulator [18]. An area measuring 4 km long and 3 km wide of Manhattan, New York was selected for the base map. Each road was set as having one lane in both directions and each lane being 3 meters wide. The OBUs and RSUs are equipped with 802.11(p) technology with a coverage area of 250 m. OBUs movement and paths are automatically generated and the minimum speed limit is set to 8 miles/hour and the maximum speed is set to 50 miles/hour, acceleration varies from 1 to 10 miles/hour and the deceleration ranges from 1 to 20 miles/hour. A total of 12 RSUs are manually distributed over the map grid, each RSU is responsible for managing a 1 km^2. To analyze if the performance of the protocol is affected by the density of RSUs, simulations were also performed with each RSU responsible for managing ½ km^2 of the map.

By using the aforementioned settings, the following studies were performed: the overhead inquired by the registration process under different data traffic densities, the data packet delivery ratio, and the average data packet delay. The data traffic generated during the simulations is CBR traffic with packet size of 512 bytes. A total of 20% of the number of OBUs on a simulation were randomly chosen as source to initiate the transmission requests and the destination nodes were changed at the end of the each transmission. The simulations were conducted a series of twenty times lasting for 2000 seconds.

B. *Results and Analysis*

The proposed protocol is first evaluated under different road traffic conditions, OBUs were randomly distributed over the 12 km^2 grid map ranging from 50 OBUs to 250 OBUs. Fig. 3 shows the total overhead generated by registration process; the results are presented as a percentage of the total data traffic in the VANETs. This overhead refers to all packets which are exchanged between OBUs and RSUs to complete the OBUs registration, and also the data traffic generated from propagating the RSU information within its region. As from the results, it is noticed that the lower the number of OBUs on the VANETs the lower the overhead incurred by the registration process, and a slight increase in overhead is noticed as the number of OBUs increase. The overhead induced by registration process is not affected by the increase in number of OBUs in the VANETs. The OBUs are only required to register one time to an RSU and re-register to the VANETs only when the OBU in his trajectory has traversed two consecutive RSUs region. Though the results show that a denser RSUs distribution on the VANETs do incur a higher overhead from the overall data traffic in the VANETs. The increase is because double the number of RSUs is used to cover the same area, this implicates that OBUs will travel shorter distances before registering again to another RSU.

The results from the simulations to obtain the amount of control data packets that are required by the protocol at various data traffic rates under different number of OBUs are presented in Fig. 4. These control data packets refer to the Destination Request (DREQ), Destination Found (DESF), Route Reply (RREP) and the Route Request (RREQ) packets used in the localization service and routing process. The rate refers to the frequency at which a source queries an RSU for the request of a route path to a destination. Fig. 4(a) shows the control data packets as a percentage from the total data traffic in the VANETs. The results obtained shows that the increase data traffic rate and an increase in the number of nodes do not significantly affect the throughput of the VANETs. This satisfactory performance is obtained from the design of the proposed protocol, since the VANET is broken into smaller manageable regions which are controlled by RSUs, this allows for controlled broadcasting of messages. This limits the flooding of Route Requests (RREQ) for any destination to a small portion of the VANETs. Thus, if the destination does not exist no further control packets are injected into the VANETs.

In Fig. 5 and Fig. 6, the results for the data packet delivery ratio under different number of vehicles and different RSU densities and the delays on the packet delivery for the protocol are shown. Each of the transmission duration time was established for as long as 5 CBR packets were exchanged from source to destination. It is observed that the lower number of OBUs on the network has the lowest data packet delivery ratio and higher time delays as fewer vehicles are registered to an RSU and fewer routes can be established from source to destination and though the destination is registered a path may not be able to be established. Also, more packets are dropped as the path routes are broken and cannot be re-established affecting the overall data delivery ratio. Whilst the high number of OBUs on the VANETs provide a good opportunity for more route paths to be established and reconnected thus increasing the data delivery and lowering the packet time delays. The use of multi-channels permits the protocol to efficiently distribute the load of packets reaching at the RSUs decreasing the probability of collisions and maintaining the overall data delivery rate. The higher delivery rate under a denser RSU distribution is because OBUs are closer to an RSU at any given time thus the route paths can be maintained for a longer period. The data delivery ratio and delivery delay times becomes independent on the number of RSUs for both scenarios, because the density of the RSUs does not necessarily contribute to the packet to be delivered it only provides the opportunity for a shorter route path but the higher volume of OBUs provides a better opportunity to prolong routing paths.

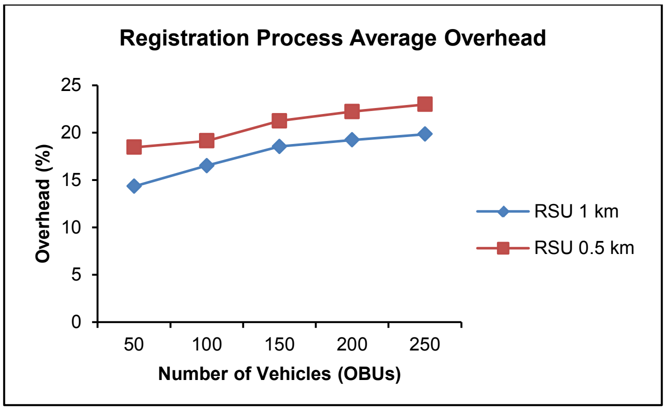


Figure 3. Percentage of packet overhead under different number of vehicles.

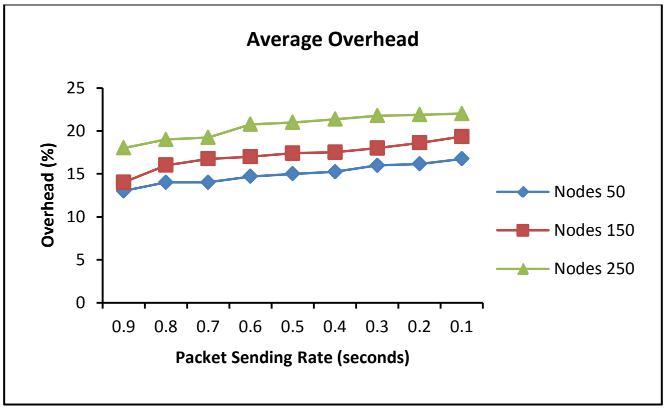


Figure 4. Average overhead under different number of vehicles and data packet sending rates.

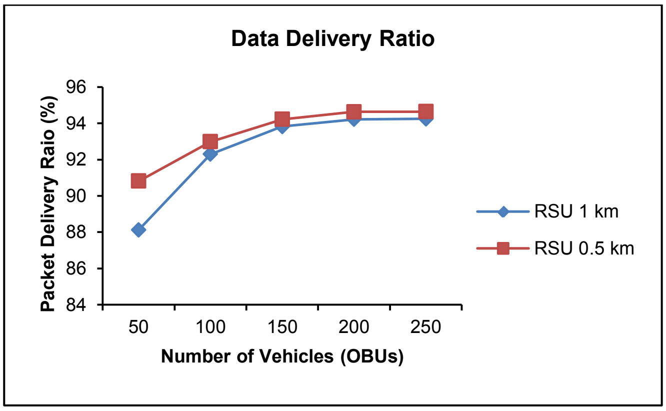


Figure 5. Packet delivery ratio under different number of vehicles.

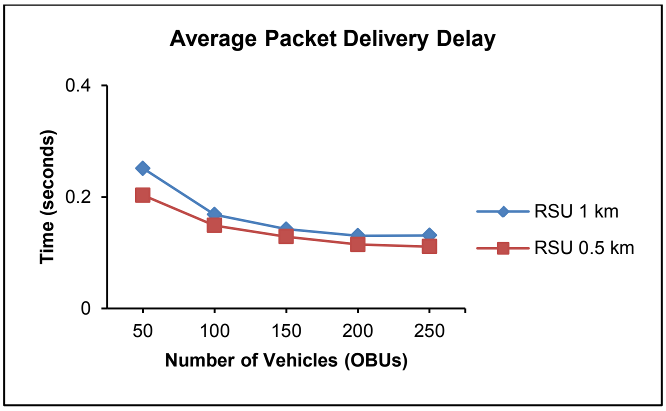


Figure 6. Packet delivery delay under different number of vehicles.

Handoffs are also considered on the evaluation performance of the proposed protocol. Fig. 7 shows the average number of handoffs from the total data traffic in the VANETs. The number of handoffs is very low, for the peculiar reason that handoffs are only considered on two conditions 1) if an OBU have traversed two consecutive RSU regions and 2) during routing where either the source or destination node moves to a new RSU region when the routing is still in progress. Thus a higher number of handoffs are accounted when the RSUs regions are smaller since the high mobility of OBUs increases the possibility of OBUs moving to a new RSU region at shorter time intervals. The increase in the number of OBUs does not affect the overall percentage of handoffs consequently handoffs are a low percentage of the overall traffic in the VANETs.

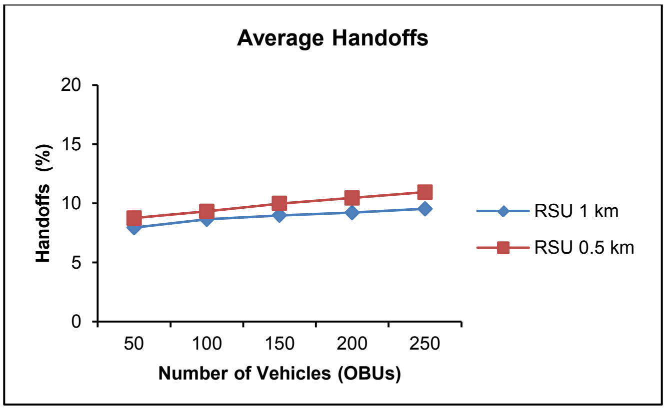
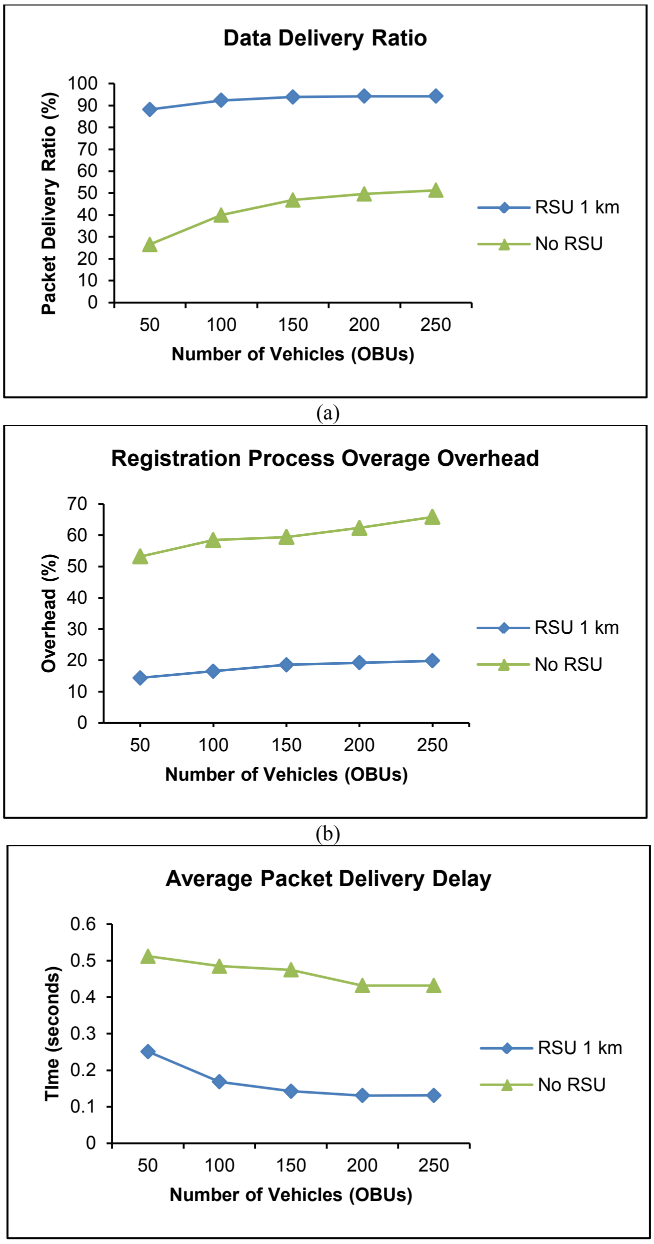


Figure 7. Average number handoffs under different number of vehicles.

Finally, the proposed protocol performance is analyzed against that of a modified version of the proposed protocol. The modified version provides the registration and localization service, except that the routing is performed only on a vehicle to vehicle communication without involving the RSUs in the routing. On the modified version of the proposed protocol when a source node wants to send packets, it first requests the RSU for the location of the destination, then the RSU responds to the source with the location and the source node is responsible for finding a path to destination without the use of RSUs. These simulations were performed to analyze the importance of the RSUs on the proposed protocol and the impact RSUs have on the VANETs. In Fig. 8, the results show that the overall performance is decreased affecting the packet delivery ratio, packet delays and increasing the overhead. The decrease in packet delivery ratio is attributed to the increase in overhead incurred in the process of requesting a route from source to destination, especially if source and destination are separated by a long distance; this increases the flooding of route requests on the VANETs. The increase of overhead packets increases the number of collision and also the longer the distance, it is more susceptible to path breaks affecting the number of delivered packets. This also increases the overall packet delays and causes an increase in the overhead. From the results it shows that the RSUs play an important role in the design of the proposed protocol and the RSU architecture presented to divide the VANETs into smaller manageable regions takes advantage of the Roadside-to-Vehicle Communications (RVC) to increase the performance of the proposed protocol.

The protocol performs well under low and high number of OBUs providing good results in overhead and delivery ratio of packets. Lower performance is noticed where there are a low number of OBUs on the VANETs. This happens because there are higher numbers of path breaks but since the RSUs are used as intermediary for routing, the effects are less felt since the route paths are shorter than the actual distance from source to destination. Also the density of RSUs has its effect, though higher number of RSU per area, decreases data packet delays and data delivery ratio there is an increase in overhead and handoffs thus a tradeoff exists on using a higher density of RSUs in the VANETs. Though there is an increase in overhead and handoffs it still performs well thus suggesting that some regions can be served by multiple RSU. This can be done in areas where the number of nodes in a region is very high.



(c)

Figure 8. The results for the modified protocol: (a) the percentage of data packet delivery ratio, (b) the percentage of overhead of the total data traffic in the VANETs and (c) the average packet delivery delay in seconds.

IV. CONCLUSION

The proposed protocol utilizes the characteristics of hybrid VANETs. It extends the capabilities of RSUs to act not only as relay nodes but also as a central repository of OBUs data. This implementation devises a registration process which allows for a localization service to be put into effect. Dividing the VANETs into smaller manageable regions controlled by an RSU allowed for an efficient system that controls broadcasting for Route Requests and also the registration of OBUs to the VANETs.

From the simulation results obtained, it is observed that the RSU architecture presented for the VANET and the localization services provides good results in throughput and packet delivery ratio. It also keeps the overhead at a low rate since the VANETs becomes divided into smaller manageable regions which are controlled by RSUs. The high percentage of data packet delivery and its low percentage of handoffs show that the proposed protocol is an efficient localization and routing protocol. Packet delays are very short between source and destination, given its unique RSU architecture and that the VANETs is divided into smaller regions it eliminates routing over long distances greatly reducing route breaks and data packets being dropped.

Future work in this paper is required to improve the proposed protocol, especially in the area of routing. The focus of the paper was in providing a localization service for source nodes wanting to establish a route to the destination for data transmission.

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