# A Location Based Delay and Packet Loss Optimized Communication Mechanism involving Handoffs in Vehicular Ad Hoc Network

M. N. Majeed[1], M. Zafrullah[2], M. A. Azam[3]

[1,2,3]University of Engineering and Technology Taxila, Pakistan
[1]nadeem.majeed@uettaxila.edu.pk

***Abstract***-Vehicular ad-hoc network faces many challenges, in particular frequent handoffs due to high mobility of vehicles is a serious performance limitation factor and is probably the most critical process in terms of packet loss and delay. In this paper an efficient mechanism of Vehicular Ad-hoc Networks (VANETs) is proposed for making handoff decision that considers both Received Signal Strength (RSS) and Global Positioning System (GPS) information along with maps. Furthermore; the proposed mechanism focuses on nodes moving at high speeds while receiving and saving the relevant information in buffers. This particular approach not only minimizes delay and packet loss but is also used to retransmit the lost packets locally. The addition of this capability in the proposed mechanism contributes in improving the packet loss in less crowded areas having limited available connectivity.

***Keywords***-Ad-Hoc Networks, Mobile Ad-Hoc networks, Vehicular Ad-Hoc Networks, Intelligent Transport System, Short Range Communication

## I. INTRODUCTION

Over the past few years, a lot of research has been done in the area of mobile ad-hoc networks (MANETs). In MANETs mobile nodes can connect and communicate with each other via one-hop or multi-hop communication links without the need for an infrastructure [i].

A VANETs is a special type of MANET having fewer limitations as compared to MANETs. In VANETs the movement of vehicles is predictable as they always move on predefined roads and the infrastructure only caters for movements along the road. Secondly, VANETs face no limitations of resources such as power or processing capabilities as almost all the devices have adequate power provided by their host vehicles. Thirdly, in VANETs all the messages are delivered by using broadcast instead of unicast [ii].

Mainly two types of communication modes are used in VANETs, Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I), both having connectivity issues as their prime problem. In V2V, variation in speed and high densities of traffic often results in low data transfer rates and limits the communication. In V2I mode, data communication rate is slower on highways due to the limited availability of Road Side Units (RSUs) [iii, iv]. The main considerations in design of VANETs solutions are to minimize delay and packet loss during communication.

Delay sensitive Intelligent Transportation System (ITS) applications (e.g., safety-related solutions) and value-added applications (such as entertainment and mobile commerce) require continuous Internet connectivity with minimum delay and packet loss [v]. Most of the VANETs applications require seamless mobility, with accessibility and service continuity, regardless of location and technology used. Many delay sensitive applications require fast handover. Fast handover is a crucial requirement to fulfil specially in small coverage networks like Wi-Fi etc. because vehicles spend only a short period of time at each access point due to their high speeds.

In this paper, we propose a novel approach that not only considers RSS parameters but also considers GPS location information along with maps for handoff decision. RSS alone, in fact is not considered much reliable for handoff decision as its accuracy may fluctuate significantly, especially in VANETs scenarios which can cause unnecessary handovers leading to delay and packet loss [vi].

We propose that every vehicle has a GPS enabled scanning module which scan and query the nearby vehicles to get their directions and speeds through on-board GPS enabled scanning module. The scanning module in each vehicle makes a queue of all available vehicles for connection. The vehicles with maximum availability (connectivity duration) are put on top of the queue and given priority. This will minimize the time to find the next best available vehicles for connectivity. When the connection from the previously connected vehicle is about to end then the next best available vehicle will be maintained on top of the queue by the scanner module. This will minimize the delay time in transmission during routing and switching between vehicles.

The proposed system focuses on nodes moving and receiving information as well as saving the relevant information in buffer. This particular approach not only minimizes the packet loss but also helps to retransmit the lost packets later on. The addition of this capability in the proposed system contributes in improving the packet loss in less crowded areas having limited available connectivity. Packets are stored in the buffer before handoff takes place and the RSS level is about to reach its threshold level, the data packets for transmission are buffered and during handoff process the dropped packets are retransferred.

Rest of the paper is as follows: section II discusses the literature review, section III contains system mechanism, results and discussion is in section IV and conclusion is in section V.

## II. Literature Review

As in today's world VANETs seems to be among one of the most emerging techniques, therefore one of the challenging research questions relating to VANETs is the Mobility management that helps in supporting a wide range of intelligent communication system based applications. The importance of VANETs for executing seamless inter-vehicle communication is quite appreciable because they offers infrastructure-less, economic and easily configurable communications. However, the integration of Interne requires a corresponding mobility assistance of the underlying vehicular ad-hoc network. Ravi and Neeraj [vii] have studied the network mobility method in detail in the context of vehicular ad-hoc network and proposed the model that has described the shifting of vehicles within several networks while they are moving. Their proposed handoff method was efficient at reducing the handoff latency and the overhead occurring due to packet loss.

The problem of finding the dead and blind spots and identifying out of coverage areas are severe problems occurring in the rural and some parts of the urban areas as the network infrastructure has not been deployed in those areas [viii]. For handling these issues a novel approach i.e. the hop to hop relay approach for vehicular transmissions has been proposed in order to extend the range of coverage and reducing the frequently generating handoffs. The proposed scheme [ix] allows for continuous connection of vehicles to the roadside infrastructure network which is the Universal Mobile Telecommunication Service (UMTS) for this particular research based project. The discovery of Relay vehicles and selection of the gateways have been discussed and investigated in detail. The proposed architecture of VANETs can be executed on top of any of the available routing protocols. The basic gateway selection have provided the finest performance with Ad hoc On-Demand Distance Vector (AODV) on top as compared to Destination-Sequenced Distance-Vector (DSDV).

Ankita and others [x] have introduced a cluster based method in their paper for implementation of VANETs. As VANET is an enhanced version of MANET, therefore several handoffs related problems that could not be removed earlier in MANETS have easily been removed using this proposed cluster based approach in VANETs. For implementing this infrastructure in VANETs, cluster oriented routing has been employed, by using AODV and AODV+ as the two routing protocols.

In VANETs, the fast moving vehicles and the limited coverage areas of 802.11 devices have made the Mobility Management as one of the challenging tasks to accomplish. This fast movement of vehicles leads to frequent occurrence of handoffs. The handover results in reducing the throughput of the network and causes sudden interruptions in previously build connections. The movement of vehicles in VANETs is assisted by the Mobile IPv6. Some of the most apparent issues of MIPv6 are the enhanced latency, packet loss and triangular routing. Therefore, a handoff structure based on FMIPv6 and HMIPv6 has been proposed [xi] that will eventually results in the lessening 802.11 based handoff latency by eradicating the DAD procedure and also by addressing other associated issues that rises when the structure is applied to the vehicular network.

Many wireless communication mechanisms have been anticipated for VANETs, such as IEEE802.11p is recommended for supporting the small to medium range transmissions in order to cope with the features of vehicular network environments [xii]. The vehicles in these environments are characterized by higher range of mobility which results in frequent disruption of already existing connections. Still, the task of mobility management is quite an attractive and challenging task particularly for VANETs and IEEE802.11p. Zagrouba and others [xiii] have proposed a new method of the handoff for the standard IEEE802.11p in perspective of the vehicular transmissions. The proposed handoff algorithm has been based on vehicle to infrastructure communications and helps in tackling the issues that have been caused either by listening the announcement of the frame service by the vehicle residing on the CCH based channel or by anticipating the full handover period before it begins. The results of simulation and evaluation of performance have shown that the proposed arrangement can reduce the handoff delay and the packet loss quite efficiently.

Hybrid Wireless Vehicular Network originates by integrating several types of networks to exploit their paybacks and optimize the overall network performance. The task of achieving ubiquity is quite difficult in the presence of several different network types. The aim of the proposed architecture [xiv] is to achieve pervasiveness in Hybrid Wireless Ad-Hoc Networks, which is done by decreasing the handoff delays originating during the handoff mechanism and the existence of moving vehicular network nodes helps in removing the power constraint imposed on the moving nodes. The idea of choosing Ideal Access terminal has been presented in order to attain fast and quick handoff by means of the Early Handoff procedure.

In most of the previous work no one has used the pre scanner to make the queue to make the handoff fast. Our proactive technique find the next node for handoff well before the handoff process. This leads to minimize the time required for handoff.

## III. SYSTEM MECHANISM

The proposed mechanism of VANETs is implemented in a highway scenario where vehicles on the road are moving in two directions. The two way roads are further divided into four lanes. The base stations are deployed at both sides of the roads but at alternate positions. There is only one road side unit (RSU) providing transmission facilities to both sides of the roads up to 500 meter. This range depicts the region of connectivity for the current base station. A network may be comprised of several base stations. The vehicles moving in connectivity zone of a base station can smoothly switch between various base stations by initiating the handoff process. The devised algorithm works for handover optimization on the basis of RSS. The idea is to implement handoff before the link failure occurs. This complete scenario is shown in Fig. 1

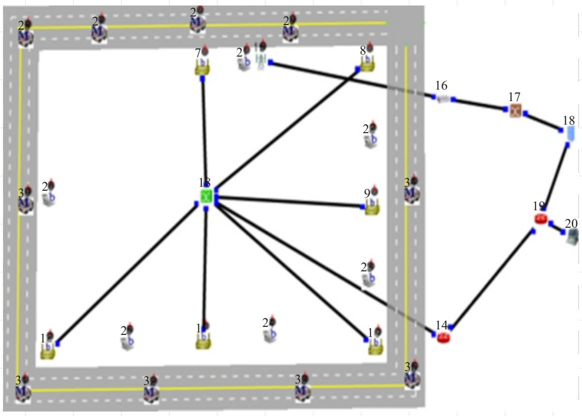

Fig. 1. System Structure

Vehicles communicate directly with the base stations or through other vehicles directly in range of base station. Whenever a moving vehicle i.e. a source vehicle senses the low received signal strength in its current connectivity range, it goes for a handoff process by checking the neighbouring cells having signal strength greater than the current one. The source vehicle sets the minimum value of its RSS in the current connectivity as a threshold value 'Y'. In case of reduced signal strength from the current cell boundary, the source vehicle firstly checks the RSS for the base station it is currently connected to, if the RSS still exceeds the threshold value than there is no need of handoff and the vehicle remains attached to the current base station.

The second case arises when the RSS from the currently connected base station lags behind the fixed threshold value. In such scenario, the source vehicle then searches for neighbouring cells except the current one having signal strength greater than the threshold value 'Y'.

**Algorithm 1:** Vehicle to Vehicle Handoff

```
Input: Vehicle to Infrastructure Threshold y, Vehicle to Vehicle
       Threshold z, Initial buffer size w, Vehicle Queue Q
Output: Connect with RSU/Vehicle
while true do
  RSU_c ← CurrentRSU Strength
  if RSU_c > y then
    Keep with current RSU
    continue
  newRSU:
  w = w + 5 (No RSU found increase buffer size)
  RSU_n ← New RSU Strength
  if RSU_n > y then
    Connect With New RSU
    continue
  vehicleQueue:
  Q = scanner(); Get current queue from scanner module
  if length(Q) == 0 then
    Buffer data and disconnect
    continue
  V_Q = dequeue(Q) Vehicle from queue with max signal strength
  if RSU_VQ < y then
    goto vehicleQueue:
  Connected to RSU_VQ via intermediate vehicle
  while true do
    if RSU_VQ < z then
      break; (RSS not satisfied start again) |
```

### A. *Checking the Desired Signal Strength*

The algorithm works in a flow where a source vehicle originates the communication process with one of the neighbouring vehicles as shown in algorithm 1. To achieve the desired connectivity, the source vehicle checks the RSS of the neighbouring vehicles. When the source vehicle finds a neighbouring vehicle with signal strength greater than the currently connected vehicle, the source vehicle tries to connect with the new vehicle. Each vehicle sets a threshold value 'Y' of received signal strength; which is the lower bound of threshold value.

For the purpose of initiating the handoff process the vehicle starts adjusting its packet's window size. When the vehicle sense lower RSS, it immediately starts increasing the packets window size. This will eventually lower the rate of sending and receiving packets, which ultimately results in low packet loss and reduced delay that mostly occurs due to handoff initiation process.

### B. *Scanning Of Neighbouring Vehicles for Handoff Generation*

The handoff occurrence process requires scanning of the neighbouring vehicles moving in the same direction as the source vehicle. The scanning module has been introduced in the proposed algorithm for the purpose of implementing the handoff process and finding the vehicle with best possible RSS. The scanning of vehicles is accomplished through GPS coordinates. The scanner then filter out the vehicles with best RSS and checks the selected vehicles for their speed, direction and velocities. If the scanner failed in searching any desired vehicle then the handoff process will be delayed till the presence of some nearby vehicle is suspected. The searched vehicle with almost similar speed and direction is selected for initiation of handoff process and the scanned results of the remaining vehicles with same direction and approximately same speed are shifted to the queue for later usage. The oppositely moving vehicles among the scanned vehicles are discarded as communication to these vehicles can no longer survive and therefore are not required in the process of handoff implementation.

### C. *Introducing Queues for Handoff Generation*

As shown in algorithm 2, the vehicles added to the queue are arranged in the FIFO order. The vehicles with best matching speed and direction are added from the front of the queue. On de-queuing the vehicle entered first will be given precedence and it will be de-queued from the rear end of the queue. When the vehicle connected to the new RSU with greater RSS again receives less signal strength from the currently connected vehicle or RSU, and then instead of re-applying the whole scanning process, the source vehicle first checks the vehicles through the queue. The vehicles in the queue are computed for their RSS value. Upon acquiring the best RSS the corresponding vehicle/RSU is selected from the queue for the purpose of handoff initiation process. Ultimately the handoff process with the resultant vehicle is carried out and the process of communication is again resumed. The window size of buffer which has been increased before the handoff process is again narrowed down to its normal value and the process of packets transmission is restarted.

**Algorithm 2:** Scanner Module

**Output**: $Q$ Queue of nearby vehicles

**while** *true* **do**
  set $P = \{V_{ss1}, V_{ss2}, \ldots, V_{ssn}\}$ of available vehicle signal strength
  **if** $length(P) == 0$ **then**
    continue
  $V_{max_{ss}} \leftarrow V_{ss1}$
  **for** $i \leftarrow 2$ *to* $n$ **do**
    **if** $V_{ssi} > V_{max_{ss}}$ **then**
      $V_{max_{ss}} \leftarrow V_{ssi}$
  $N_{GPS} \leftarrow$ GPS coordinates of vehicle having $V_{max_{ss}}$
  $d_N \leftarrow$ direction of vehicle using $N_{GPS}$
  $d_V \leftarrow$ direction of own vehicle from GPS coordinates
  $s_N \leftarrow$ speed of vehicle using $N_{GPS}$
  $s_V \leftarrow$ speed of own vehicle from GPS coordinates
  **if** $sign(d_N) <> sign(d_V)$ **then**
    continue
  **if** $s_N \approx s_V$ **then**
    $insert(Q)$
**return** $Q$

### D. *Scenario of Handoff Generation with Multiple Intermediate Nodes Involved*

While scanning process is in progress, it may be possible that the source vehicle does not find any base station in its direct range of communication. The vehicle must have been moving on the other side of the road where base station is not deployed for that specific communication zone. The source vehicle then sends the message for gathering RSS of the base station by involving the intermediate vehicle which is moving in direct communication range of the base station. The intermediate vehicles further deliver the message to its neighbouring vehicles. The process continues until the message is reached to the base station. The base station upon receiving the request message, prepares the reply message and sends it back to the intermediate vehicle which further transmits back the message parcel to the source vehicle.

The source vehicle checks the RSS of the base station with respect to the current threshold value Y. If the result is greater than Y, the source vehicle finally goes for the handoff process and shifts its connectivity to the new base station.

### E. *Scenario of Handoff Generation with Single Intermediate Node Involved*

The alternative scenario for this handoff occurs when only a single intermediate vehicle is involved in the scanning process. For such situation, the intermediate vehicle on receiving the message, computes its own RSS against the threshold value Y of the source vehicle. For exceeded value of signal strength, the intermediate vehicle directly forwards the request to its base station and the source vehicle is successfully connected to the new base station sharing the connectivity to the intermediate vehicle. The intermediate vehicle can also search for the new roadside unit if it is receiving the less signal strength than the threshold value Y. The intermediate vehicle then becomes the source vehicle and the whole searching process is repeated for the intermediate vehicle.

*F.* Setting *Threshold 'Z'for New Connection*

As shown in last step of the algorithm 1, the source vehicle sets the new threshold value i.e. 'Z' which is the minimum amount of signal strength it can receive from the new RSU. The source vehicle can enjoy communications in the networking zone of the new base station. Although, handoff has been conducted for once, yet the source vehicle keeps on checking the amount of RSS at every point against the new threshold value 'Z'. As long as the value is exceeding 'Z', the source vehicle can conduct communications. The moment it senses the value going below 'Z', the source vehicle starts searching process and the whole process of examining the signal strengths of other base stations continues. The searching process is a kind of an umbrella activity that is applied throughout the life span of vehicle on the road. The need for handoff has no end point except that the vehicle eventually reaches its destination.

The handoff process is initiated by sending the request message to the new base station for checking the signal strength of the new base station. The request message can be transmitted by forwarding through intermediate nodes or scanning the whole network. On availability of the new base station with required signal strength the handoff request is entertained.

*G. Utilization of Maps in Handoff for GPS Coordinates*

Handoff request can be implemented on the basis of information gathered through maps and GPS coordinates. The base stations are further connected to the mobile switching centres at the back end. The network servers are located at the back end mobile switching centres. All the required communications are conducted through the back end network server via base station at front end. The maps are added in the base station which provides services to the source vehicle in depicting the right path for its journey to the destination. The layout of the roads in the scenario of VANETs is organized in such a manner that it can place constraints on the movement of the vehicles. Furthermore, the movement of vehicles on the roads is strictly restricted by some traffic conditions that keep on changing at different intervals of time. The burst conditions of traffic can limit the comfortable and smooth initiation of handoff process.

The scheme of adding maps to the base stations is based on the utilization of vehicle's information for predicting the possibilities of handoff process to the neighbouring cells. The information of the vehicle includes uniform speed of the vehicle with which it is moving and the direction of moving vehicle. Along with that the base station uses information stored in the base station regarding road condition for prediction of the probability of handoff occurrence especially with the neighbouring cells. The information is stored in the map for once and then it is utilized for estimation purpose.

The information from the moving vehicles is submitted to the maps in the base stations by using GPS coordinates. All the vehicles on the road are equipped with the GPS devices that provide vehicles with the capability of predicting their accurate positions on the road. The position of the vehicles is then transmitted to the base station which is ultimately stored in the database at the base station. The base station has a back end database for the vehicles in the coverage area of the base station. The database is aimed at storing the transmitted vehicle's information required for probabilistic handoff conductance. Base station uses this information sent via GPS coordinates to perform calculations for all of the active vehicles in its coverage zone.

The above described scheme has been utilized in current research project of handoff optimization. The distinguishing feature of the scheme is that it makes use of the road information and limits the bandwidth usage to achieve efficiency in utilization of the shared resources.

*H. Advantage of Using Maps*

The vehicles are attached to the Base Stations through the back end network consuming the limited reserved bandwidth assigned to each base station. In mobile ad-hoc networks, vehicles can specifically be designated as the mobile stations. As discussed earlier, each mobile station is equipped with a GPS system for sending GPS coordinates to the Base Station. On the basis of transmitted coordinates, the Base station calculates the location of the vehicle and can further predict its path based on probabilistic approach [xv].

The base stations uses a map service for receiving GPS coordinates as reference points and defining the structure of roads hierarchy and traffic conditions in an efficient manner. Therefore, the utilization of maps can be proved as an effective approach in predicting either the current scenario of handoff or the probability of taking handoff. The overall bandwidth reserved for the network is attuned dynamically whenever there is a possibility of handoff to occur [xvi].

*I. Reasons for Generation of Handoff*

The need for initiating the handoff process is a result of the less amount of received signal strength in functional channel of the cell. The issue of reduced signal strength may arise due to various possible reasons including the maximum operating capacity of the channel, the amount of bandwidth reserved for the channel and the extreme signalling range of the channel. The operating capability of the channel depends on the number of requests arriving at the channel due to handoffs occurring in the network [xvii]. Depending on the arrived requests, the received signal strength of the channel can therefore be measured.

## IV. Experimental Setup and Evaluation Results

The experiments have been conducted on ESTINET [xviii] for different scenarios. Vehicles are equipped with devices capable of having network connections. Transmissions among the vehicles are carried out for varying parameters including frame rate, bit rate and bandwidths. Each experiment has been conducted twice, once for the 802.11p where handoff optimizations are carried out without any available scanning option. The second experiments are conducted for our proposed work which is named as Delay and Packet loss based Optimized Vertical and Horizontal Handoff algorithms (DePOVHH), where scanners are involved for pre-scanning of nearby vehicles. The experimental setup chosen for transmitting video data among vehicles is shown in Table I. The encoding scheme chosen for this specific media type is MPEG-4and maximum of 30 frames are transferred per second.

TABLE I
Video Transmission Parameters During V2V Handoff Simulation

| | |
|---|---|
| Media Type | Video |
| **Encoding Scheme** | MPEG-4 |
| **Frame Rate** | 30 frames/Second |
| **Payload Type** | 26 |
| **Bit Rate** | 150 kbps |
| **Sampling Rate** | 90kHz |
| **Bits/Sample** | 3 Bit |
| **Session Bandwidth** | 1600kbps |
| **Road Topology** | A four lane road |

As MPEG-4 format uses less bandwidth [xix, xx], therefore this encoding scheme is used with 150kbps bit rate. Simulation has been run and performance of the scanner and non-scanner algorithms is evaluated. The evaluation results are shown for delay, packet loss and throughput.

### A. *Average Packet Loss*

The simulation results in Fig. 2 and Fig. 3 shows that as the vehicle's velocity increases, the packet loss also increases. The performance of vehicle increases as compared to the existing handoff velocity in DePOVHH. The effect of DePOVHH is more prominent when the velocity of vehicle is less than 25m/s which is the optimize speed on highway, where the packet loss is less than 1000. The number of packet loss is 1297 for ten number of vehicles, where DePOVHH value is 726. This shows that DePOVHH algorithm enhanced the network performance.

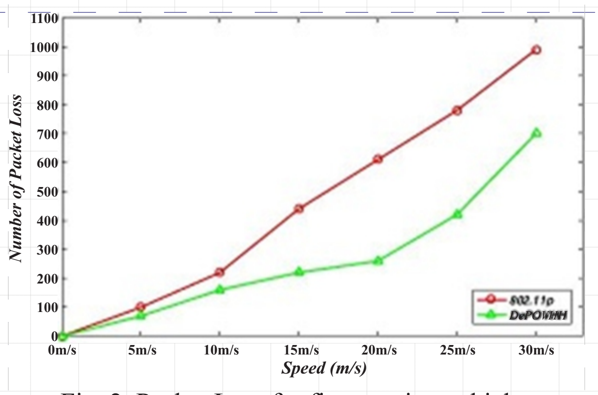


Fig. 2. Packet Loss for five moving vehicles

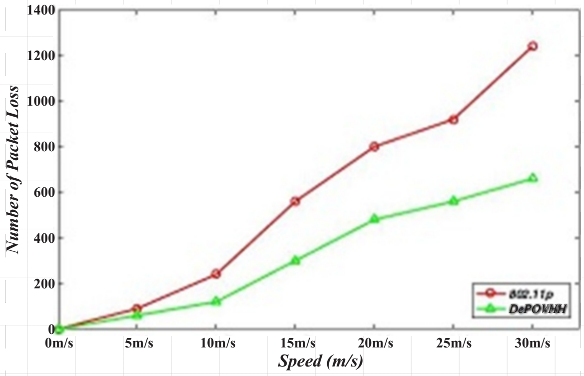


Fig. 3. Packet Loss for ten moving vehicles

### B. *Average Packet Delay*

The simulation results show that as the velocity of vehicle increases, it affects the handoff delay in every handoff algorithm. When the vehicle velocity increases then there is a little time for transmission and scanning at the same time which increased the delay, but, in DePOVHH, as the velocity of vehicle increases it has no reasonable effect on handoff delay. Because before handoff performing active scanning is performed. In the Fig. 4 and Fig. 5 indicates that the packet delay comparison for of different number of vehicles, 5and 10 respectively. The result shown that the at the velocity of 25m/s, the DePOVHH's average packet delay in 5 moving vehicles is 138.69ms, 154.73ms in 10 moving vehicles. It shows that as with the increase in number of vehicles, the packet delay also increases. The reason for that is since there are so many vehicles to establish the next connection before the signal became weak.

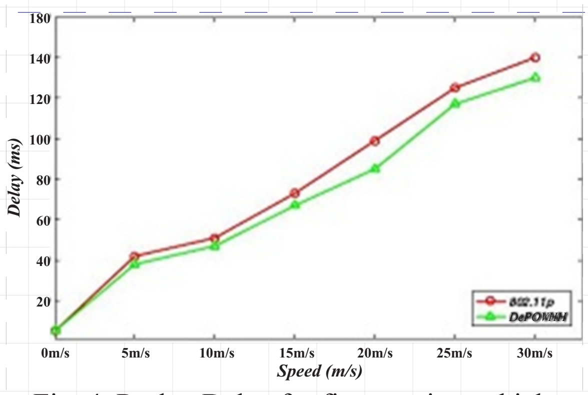


Fig. 4. Packet Delay for five moving vehicle

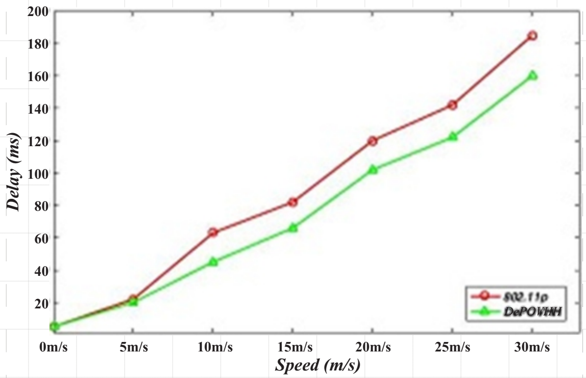


Fig 5. Packet Delay for ten moving vehicle

### C. Average Throughput

The simulation results of Fig. 6 and Fig. 7 shows the average throughput for different vehicle velocities. From the simulation result it is clear that increase in vehicle velocity greatly affect the average throughput. Packet loss and delay results in scanning phase which also affects the average throughput. As the vehicle's velocity increases, the packet lost increases and throughput decreases. From Fig. 7 it is clear that as the velocity of vehicle increases, throughput decreases for five moving vehicles. From all of these simulation results it is clear that the association and authentication process between the base station and vehicle is not much affected as the velocity of vehicle is increase.

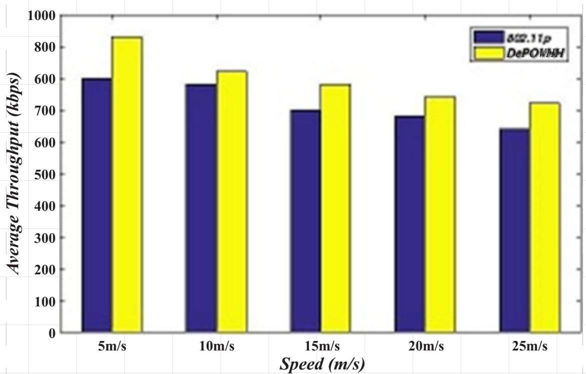


Fig. 6. Average Throughput for five moving vehicle

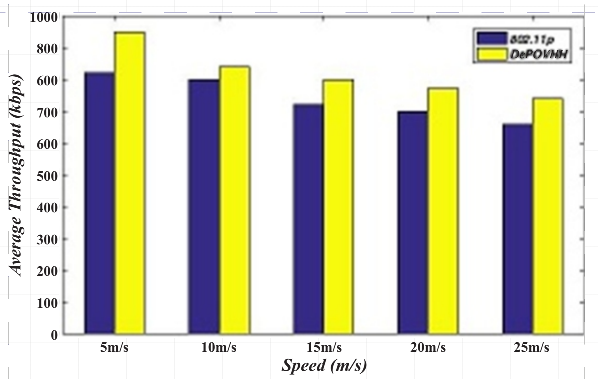


Fig. 7.Average Throughput for ten moving vehicle

## V. CONCLUSION

This research based project was aimed at providing delay tolerant optimization techniques for horizontal and vertical handoff occurrences particularly for Vehicular Ad-hoc Networks. An improved technique for handoff has been proposed that caters for delayed packet losses and frequent link failures. The underlying mechanism has been organized to provide maximum throughput while handoff process is in progress. The parameter selected for proposed algorithm to work upon is the Received Signal Strength and the desired information for smooth processing of algorithm is provided through GPS. For experimental purposes, the vehicles on the road are allowed to move randomly with varying speeds and velocities, creating a road map scenario of a two-way traffic. The optimization is achieved by introducing a scanner module through which vehicles pre-scanned their neighbouring vehicles and creates a priority queue for buffering the location of nearby vehicles. On link failure, vehicle selects the top queued item with maximum priority for immediate connectivity. This particular pre-scanning approach saves time in searching for a new connectivity and hence, proved to be the best approach in reducing amount of packet loss due to link failures. Moreover, the proposed system also offers an opportunity for buffering the relevant information of vehicles during on-going communications, which in turn can be sufficient in achieving maximum throughput even on link failure. The packets stored in the buffer are later on retransmitted on finding the new connectivity in range.

The results of simulations for the proposed algorithm clearly depicts the efficiency measure of the algorithm achieved in terms of the reduced packet loss, delay and increased throughput compared to previous approaches adopted for handoff implementation.

The algorithm can be further improved in terms of efficiency by implementing it for infrastructure optimization, where vehicles can also communicate with infrastructure.

## REFERENCES


[i] S. Lee, K. Sriram, K. Kim, Y. H. Kim, and N. Golmie, "Vertical handoff decision algorithms for providing optimized performance in heterogeneous wireless networks," IEEE transactions on vehicular technology, vol. 58, pp. 865-881, 2009.

[ii] W.-H. Kuo, S. Dong, and J.-S. Huang, "Pheromone-based v2v unicast routing scheme in vanets," in Connected Vehicles and Expo (ICCVE), 2013 International Conference on, 2013, pp. 783-784.

[iii] V. Palma and A. M. Vegni, "On the Optimal Design of a Broadcast Data Dissemination System over VANET Providing V2V and V2I Communications" The Vision of Rome as a Smart City"," Journal of telecommunications and information technology, pp. 41-48, 2013.

[iv] E. C. Eze, S. Zhang, and E. Liu, "Vehicular ad hoc networks (VANETs): Current state, challenges, potentials and way forward," in Automation and Computing (ICAC), 2014 20th International Conference on, 2014, pp. 176-181.

[v] E. C. Eze, S.-J. Zhang, E.-J. Liu, and J. C. Eze, "Advances in vehicular ad-hoc networks (VANETs): Challenges and road-map for future development," International Journal of Automation and Computing, vol. 13, pp. 1-18, 2016.

[vi] M. Louta and P. Bellavista, "Bringing always best connectivity vision a step closer: challenges and perspectives," IEEE Communications Magazine, vol. 51, pp. 158-166, 2013.

[vii] R. S. Shukla and N. Tyagi, "Global mobility and handover management for heterogeneous network in VANET," International Journal of Next-Generation Networks 5(2/3): 23. , 2013.

[viii] I. W.-H. Ho, S. C. Liew, and L. Lu, "Feasibility study of physical-layer network coding in 802.11 p VANETs," in Information Theory (ISIT), 2014 IEEE International Symposium on, 2014, pp. 646-650.

[ix] M. A. Alawi, R. A. Saeed, and A. A. Hassan, "Cluster-based multi-hop vehicular communication with multi-metric optimization, " in Computer and Communication Engineering (ICCCE), 2012 International Conference on, 2012, pp. 22-27.

[x] A. Anand and P. Singh, "Performance optimization of vehicular ad hoc network (VANET) using clustering approach," in Computer Networks & Communications (NetCom), ed: Springer, 2013, pp. 205-212.

[xi] M. N. Khan, I. Wahid, and G. Mehmood, "A Global Mobility Management Scheme for Reducing Overall Handover Latency in IP based VANETs," International Journal of Ad Hoc, Sensor & Ubiquitous Computing, vol. 3, p. 11, 2012.

[xii] R. Zagrouba, H. Hayouni, and F. Kamoun, "Handover optimization within vehicular networks," in Computer Applications and Information Systems (WCCAIS), 2014 World Congress on, 2014, pp. 1-5

[xiii] N. Gupta and M. Dave, "Early Handoff mechanism for integrating VANET into Hybrid Wireless Network," in Advances in Technology and Engineering (ICATE), 2013 International Conference on, 2013, pp. 1-7.

[xiv] A. F. Santamaria, C. Sottile, F. De Rango, and M. Voznak, "Road safety alerting system with radar and GPS cooperation in a VANET environment," in SPIE Sensing Technology+ Applications, 2014, pp. 91030G-91030G-14.

[xv] D. Bektache, C. Tolba, and N. Ghoualmi-Zine, "Forecasting approach in VANET based on vehicle kinematics for road safety," International Journal of Vehicle Safety, vol. 7, pp. 147-167, 2014.

[xvi] C. Han, M. Dianati, R. Tafazolli, R. Kernchen, and X. Shen, "Analytical study of the IEEE 802.11 p MAC sublayer in vehicular networks," IEEE Transactions on Intelligent Transportation Systems, vol. 13, pp. 873-886, 2012.

[xvii] S.-Y. Wang, C.-L. Chou, and C.-M. Yang, "EstiNet openflow network simulator and emulator," IEEE Communications Magazine, vol. 51, pp. 110-117, 2013.

[xviii] C. Rezende, A. Boukerche, H. S. Ramos, and A. A. Loureiro, "A reactive and scalable unicast solution for video streaming over VANETs," IEEE Transactions on Computers, vol. 64, pp. 614-626, 2015.

[xix] T. Tsuboi and T. Sekiguchi, "Optimization for Wireless Vehicular Network System in Urban Area,"in Nets4Cars/Nets4Trains/Nets4Aircraft, 2014, pp. 126-142.

[xx] S. Cespedes, N. Lu, and X. Shen, "VIP-WAVE: On the feasibility of IP communications in 802.11 p vehicular networks," IEEE Transactions on Intelligent Transportation Systems, vol. 14, pp. 82-97, 2013.

[xxi] B. Saranya, V. Sakthika, R. Vijiyalatha, M. N. Begin, and S. R. Anand, "Efficiently Design For Cross Layer Optimization Using Handover Scheme in Vehicle Adhoc Networks," International Journal of Scientific Engineering and Technology, vol. 3, pp. 698-702, 2014.

[xxii] M. H. Eiza and Q. Ni, "An evolving graph-based reliable routing scheme for VANETs," IEEE Transactions on Vehicular Technology, vol. 62, pp. 1493-1504, 2013.

[xxiii] F. Aadil, S. Khan, K. B. Bajwa, M. F. Khan, and A. Ali, "Intelligent Clustering in Vehicular ad hoc Networks," TIIS, vol. 10, pp. 3512-3528, 2016.