Multipath Routing in VANET: Multi-Agent based Approach

Anil D. Devangavi
Information Science and Engg., Basaveshwar Engineering College, VTU,
Bagalkot, India
anildevangavi_s@yahoo.co.in

Rajendra Gupta
Research Cell, AISECT University,
Madhya Pradesh, India
rajendragupta1@yahoo.com

Abstract— In VANET routing of data is a exciting task owing to the high dynamics involved in this network. Delivery of data to the projected destination turns out to be very puzzling. Single path routing suffers from drawbacks like unreliability and etc. To manage such situation multipath data delivery is very nominal. In multipath routing more than one path discovered between source and destination node. Data packet can be sent simultaneously in all paths or data packet can be send by selecting path one after another. It is up to the routing algorithm to select path thoughtfully to deliver data proficiently. However existing multipath routing protocols even though compute multipath, only one path will be engaged in actual communication at any given time. Hence this work proposes Multipath Routing in VANET: Multi-agent based Approach which calculates multiple paths amongst source and destination. Further, all such computed paths will be employed for information dissemination. NS2 simulation of the proposed approach in realistic mobility models show that it can select more stable link and improve the network performance.

Keywords- *Multipath, Node-disjoint, Congestion.*

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I. Introduction

Vehicular Ad hoc Network (VANET) is a variety of network intended for V2V (vehicle-to-vehicle) and V2I (vehicle to infrastructure) communication It is a core part of Intelligent Transportation System (ITS) and is being extensively researched now a days. Unique characteristics of VANET are no energy resource constraint, high mobility patterns, relatively high moving speed. During the transit of information through multi-hop routing, if an intermediate link was broken, the path needs to be rebuilt or restored. Hence, efficient routing protocols are essential to function properly. Multi-path routing protocols aim to compute several paths during the discovery phase between sender and receiver. Such network has been extensively used in battle field, disaster management, under water network etc. Advantages of multipath routing are 1) Load Balancing 2) Fault Tolerance 3) Higher Aggregate Bandwidth 4) Lower Delay 5) Reduced Congestion and improved QoS 6) Higher resiliency 7) Increased network lifetime [1].

Multipath routing protocols compute node disjoint, link disjoint or non-disjoint routes in the course of route discovery Process. Node-disjoint routes have completely disjoint routes where there are no nodes or links in common. Link-disjoint routes have no links in common but may have nodes in common. In an ad hoc network, identification of all node-disjoint paths between a given pair of nodes is a challenging task [2].

Rest of the paper is organized as follows. Section I. A discusses related works. In section I. B methodology is presented. In section II structure of the proposed work is discussed. Network environment is mentioned in section II. A. Section II. B discusses mathematical models. Section II. C describes the proposed agency. The proposed scheme for the work is stated in section II. D. Section II. E describes the algorithm for the proposed work. Simulated model for the proposed work is discussed in section III. Results and analysis are discussed in section IV. Conclusion is presented in section V.

A. Related Work

Authors in [3] propose a novel road topology-aware routing (RTR) protocol for VANETs. To adequately utilize connected routing paths RTR creates two junction-disjoint paths. RTR alternately transfers data packets through each established routing path and dynamically changes the routing path based on the connectivity of the current path. Authors in [4] propose Junction-based Multipath Source Routing (JMSR) a geographic routing protocol which exploits the location of the nodes and street junctions. Two concurrent paths from the source to the destination are preserved as a series of junctions the packets should pass through. Routing information is injected in each packet. As such every node on the path is aware of the route, packets to go ahead. Authors in [5] propose distributedly finding disjoint paths (DFDP) to compute k disjoint paths from source to destination. Further they analyze the relationship between disjoint paths and network parameters like robustness, throughput, and load balancing. Authors in [6] propose link-disjoint, node-disjoint and zone disjoint multi-path algorithms aiming on the compromise between lifetime and hop count of routes for MANET. Authors in [7] evaluate the applicability of node disjoint multipath in VANET environment. Through simulation results author‘s present that it improves the packet delivery ratio and reduces the end-to-end delay. Authors in [8] present a modified form of AOMDV known as Maximally Spatial Disjoint Multipath routing protocol (MSDM) for MANETs. The data is communicated employing multiple paths which are mostly spatially separated and node-disjoint paths. Results show that spatially node-disjoint routes perform better than AOMDV which selects only link-disjoint paths.

Authors in [9] propose a 2path routing protocol which is a special case of multipath routing. Two paths are recognized amongst source and destination. The nodes contributed in path-1 and path-2 forms a connected graph. Non-interference is guaranteed as no edge shared between path-1 and path-2. Authors in [10] present AODV based node disjoint multipath routing protocol. They focus on residual energy of nodes and discovery of multiple node disjoint paths with low routing overhead. Authors in [11] propose a node disjoint multipath protocol based on AODV with additional features data security during transmission and link failure. Routing overhead is substantially reduced because through a single flooding of a RREQ message route discovery and maintenance process is completed. Authors in [12] propose a multipath routing protocol which integrates dynamic clustering and ant colony optimization. The routing protocol focus on issues related to energy consumption nodes. The cluster head are elected considering residual energy. Multiple paths between cluster head and destination node are computed by ACO. Final selection of route is based on energy consumption of individual paths by cluster heads. Network lifetime is thus increased reducing node energy consumption.

Disadvantages of the existing system:

- Complexity.
- Extra overhead.
- At low bit rate there will be more end-to-end delay.

B) *Methodology*

In this paper, we propose a new approach for Multipath Routing in VANET: Multi-agent based Approach. Every vehicle in the VANET is connected to at least one RSU at any given time. We use an approach where multiple node disjoint paths are employed between sender and receiver. The proposed work thus aims to optimize congestion focusing on multipath routing. Accordingly information is communicated from sender vehicle to destination vehicle over multi paths simultaneously.

The proposed scheme works as per the following procedure:

1) Source vehicle identifies destination.
2) Source vehicle triggers mobile agent and creates m clones of it.
3) The clones (m clones) of the mobile agent thus created computes neighbouring nodes (next intermediate node) and migrates to them.
4) The process in step 3 is repeated at each intermediate vehicle until every clone reaches destination. Multiple paths to destination are thus calculated.
5) Destination triggers a static agent to compute n node disjoint paths amongst multiple paths computed in step 4 [15].
6) Destination triggers a static agent to compute the weight factor of each n path. Weight factor of a path between any two vehicle nodes is based on the parameters like mobility of intermediate vehicles in the path, bandwidth utilized, trust value (behavior) of the intermediate vehicle on the path. It then prioritizes the n paths based on weight factor with path having higher weight factor at the top [16].
7) Destination communicates the priority list to the source vehicle along the best path (path with highest weight factor).
8) Source vehicle determines the context of the information to be sent.
9) If the context is critical, Source communicates the information on all the paths employing all paths. Else the information is communicated along the best path to the destination.

Our contributions are as follows:

- Use of agent technology to compute multipath.
- Use of agents to compute node disjoint paths
- Reduced communication cost owing to the use of mobile agents
- Various agencies are employed to gather information of intermediate nodes on the multiple paths and to prioritize the multiple paths.

The proposed work Multipath Routing in VANET: Multi-agent based Approach (MRMA) is compared with 2 Path Routing Protocol (2PR). The advantages of proposed approach over 2PR are as follows:

- Optimization of congestion.
- All the calculated paths are positively used.
- Higher reliability.
- Competent usage of bandwidth.

II. Structuring the Proposed Ssystem

This section presents the network environment, network and mathematical models, proposed agency, scheme and algorithm.

A. *Network Environment*

The network structure is depicted in Figure 1.

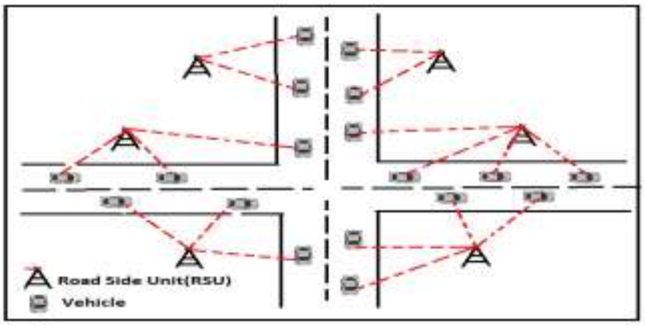

Figure1. VANET Environment

The above figure presents the network environment in which we can notice that number of vehicles move with different speed in different lanes. Some of the assumptions in this work are: RSU exists at regular intervals and all the RSUs are networked, each vehicle is connected to at least one RSU at any given time, all vehicles and RSUs are fitted with GPS. The location of RSUs is known to one another, Information of all incoming and outgoing vehicles is updated in the database of RSU. The database of RSU is updated with information like current position of vehicle, vehicle's mobility and direction. Each vehicle communicates with other vehicle within its communication range (V_{RAN}) via V-to-V communication with road side units via V-to-R communication. The vehicles that lie within the transmission range of a particular vehicle are the neighbouring vehicles of that vehicle. Each vehicle's status and information (parameters) is updated by itself and also by neighbouring vehicles in a local database. The information is

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related to vehicle ID, position of the vehicle in terms of latitude and longitude, current speed of the vehicle, direction and etc. Every vehicle is connected to at least one road side unit (fixed infrastructure).

B. Network and Mathematical Models

This subsection deals with the network and mathematical model for the proposed work.

1) Network Model

Link disjoint paths are the path between pair of nodes with no link in common between the node pair [13]. Node disjoint paths are path between pair of nodes where no node is common except source and destination. The node disjoint path is also link disjoint in nature as no link is common in node disjoint path between source and destination node. However link disjointis not always node joint because several links may share node. In figure 2 three different link disjoint paths shown between S (source) and D (Destination) node are S-a-b-c-d-D, S-i-k-e-g-D and S-me-f-D. The last two paths share the node e. In figure 3 there are two node disjoint paths shown between S and D node S-a-b-c-d-D and S-e-f-g-h-D. They do not share any node.

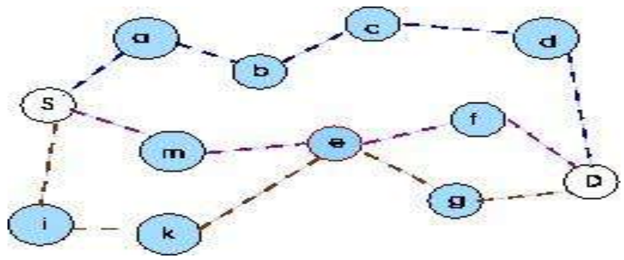

Figure 2.Link Disjoint Path

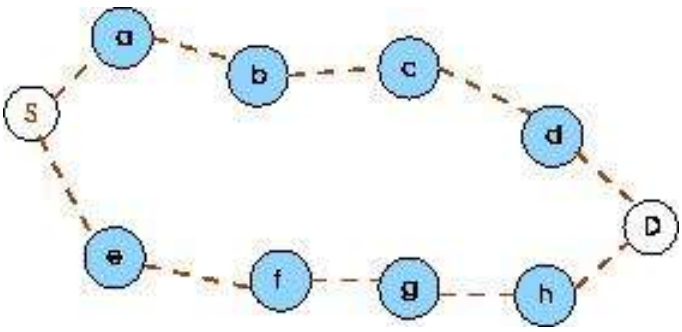

Figure 3.Node Disjoint Path

In general a path is sequence of vertices: s, v_1.... v_ m, t. Two paths s, v_1.... v_ m, t and s, u_1.... u_ m, t are called node-disjoint if v_ i ! = u_ j for any valid I and j.

2) Path weight factor

Path weight factor of each path (Pw) is computed as follows. Let
MA be the average mobility of the vehicles on the path B_{AVP} be the bandwidth available on the path and V_{DEN} be the density of the vehicles on the path Priority of the path (P_R) is directly proportional to bandwidth available on the path (B_{AVP}), the density of the vehicles on the path (V_{DEN}) and inversely proportional to the average mobility of the vehicles on the path (M_A) (Eq. 1).

$Pw \; \alpha \; B_{AVP}$
$Pw \; \alpha \; V_{DEN}$
$Pw \; \alpha \; 1/M_A$
$Pw \; \alpha \; B_{AVP} * V_{DEN} / M_A$

$$Pw = P * B_{AVP} * V_{DEN} / M_A \text{ (where P is a constant)} \qquad (1)$$

C. Proposed Agency

Various agencies are employed to perform communication among vehicles and road side units viz. Vehicle Agency, Road Side Unit Agency [14] [15][16] [17].

Vehicle Agency: Vehicle Agency consists of a set of static and mobile agents like Vehicle Manager Static Agent (VNSA), Vehicle Manager Knowledge base (VMK) and Path Requester Agent (PRA).

Vehicle Static Manager Agent: It is a static agent residing in every vehicle. It is responsible for creating all other static and mobile agents and knowledge base. It also synchronizes the agent interactions. It keeps track of parameters like speed, direction, location, status and unique vehicle ID of the parent node. It stores the relevant information in VMK. VSMA of source vehicle triggers mobile agent Multipath Finder Mobile Agent (MFMA) whenever path is required to destination. VSMA of the destination triggers static agent (NDPF) to compute node disjoint paths amongst the multiple paths computed. VSMA of the destination triggers static agent (MPE) to assign priorities to each node disjoint path computed.

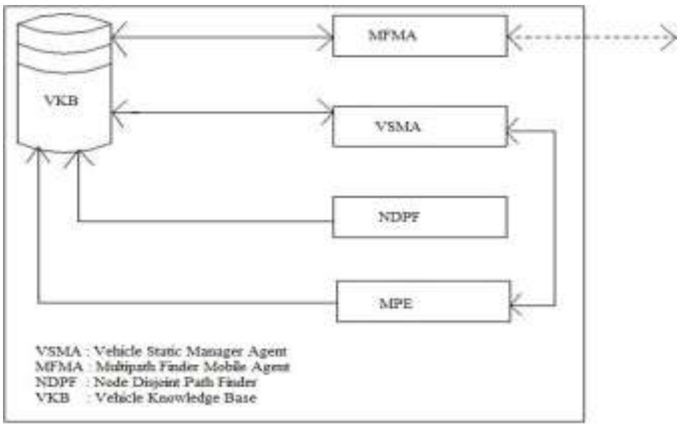

Figure 4.Vehicle Agency

VSMA of the destination then communicates the prioritized list of paths to the source along the best path (path with highest weight factor). It is the responsibility of VSMA to decide on the no. of paths, based on the context to be used from the priority list to communicate the information. If the context of the information is critical then the information is communicated employing all paths. Else information is communicated to be source along the best path.

Vehicle Knowledge Base: It is the repository of the vehicle. All the agents store the relevant information in this repository. It resembles blackboard and enables agent interactions. It stores the parameters like speed, direction, location, status and unique vehicle ID of the parent node and neighbour vehicles.

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Multipath Finder Mobile Agent (MFMA): It is a mobile agent triggered by VSMA of source vehicle. Clones of MFMA computes and migrates to next neighbour vehicles till they reach destination. Multiple paths are thus created.

Node disjoint Path Finder: It is a static agent triggered by VSMA of destination vehicle with list of multiple paths as input parameter. It computes all possible node disjoint paths amongst the multiple paths.

Multiple Path Evaluator: It is a static agent triggered by VSMA of the destination. It computes the weight factor of all the node disjoint paths. Weight factor of a path between any two vehicle nodes is based on the parameters like mobility of intermediate vehicles in the path, bandwidth utilized, trust value (behavior) of the intermediate vehicle on the path. It then prioritizes the n paths based on weight factor with path having higher weight factor at the top.

Road Side Unit Agency: It consists of a set of static and mobile agents viz. Road Side Unit Manager Static Agent (RMSA), Roadside Unit Knowledge Base RKB and Behavior Predictor Agent (BPA).

Roadside unit Static Manager Agent: It is a static agent which resides in every roadside unit. It allocates specific task to all the created agents and synchronizes the agent interactions. It monitors the information of incoming vehicles and outgoing vehicles. The behavior of each outgoing vehicle is communicated to neighbour RSU.

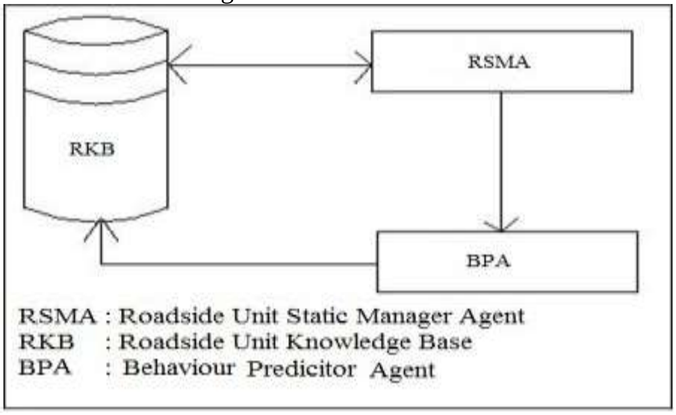

Figure 5.Road Side Unit Agency

Behavior Predictor Agent (BPA): This is a static agent residing in every RSU. It keeps track of the behavior (speed, direction and etc.) of each vehicle in the range of parent RSU. Using this information it predicts the future behavior of the vehicle. The relevant information is stored in RKB.

Roadside Unit Knowledge Base (RKB): This is the repository residing in each RSU. It stores the information of incoming and outgoing vehicles. It also stores the information regarding the behavior of each vehicle.

D. Proposed Scheme

- Source identifies destination.
- The VSMA of the source triggers Multipath Finder Mobile Agent (MPFA) and creates m clones of it.
- The clones (m clones) of MPFA thus created computes neighbouring nodes (next intermediate node) and migrates to them [18].
- The process in step 3 is repeated at each intermediate vehicle until every clone reaches destination. Multiple paths to destination are thus calculated [19] [20].
- The VSMA of destination triggers Node Disjoint Path Finder (NDPF) to compute n node disjoint paths amongst multiple paths computed in step 4 [21] [22].
- The VSMA of the destination triggers Multiple Path Evaluator (MPE). MPE computes the weight factor of each n path. Weight factor of a path between any two vehicle nodes is based on the parameters like mobility of intermediate vehicles in the path, bandwidth utilized, trust value (behaviour) of the intermediate vehicle on the path. It then prioritizes the n paths based on weight factor with path having higher weight factor at the top [25].
- The VSMA of the destination communicates the priority list to the source vehicle along the best path (path with highest weight factor).
- The VSMA of the source vehicle determines the context of the information to be sent.
- If the context is critical, VSMA of the source communicates the information on all the paths employing all paths. Else the information is communicated along the best path to the destination.

E. Algorithm

Assumptions:

- All the RSUs are networked.
- Each vehicle is connected to atleast one RSU at any time.
- All vehicles and RSU fitted with GPS. The location of RSUs is known to one another.

Algorithm for the communication of information along multipath to the destination is as below:

Input: A set of vehicles V= {V1…...Vn}
A set of RSUs R= {R1………Rn}
Every vehicle has vehicle agency, RSU has RSU agency.
Let V_S: Source Vehicle and V_D: Destination Vehicle
D_L: Location of destination vehicle
$VSMA_S$: VSMA of source vehicle
$VSMA_D$: VSMA of destination vehicle

Algorithm 1: To Communicate information along multipath to destination

Begin
$VSMA_S$ identifies V_D;
$VSMA_S$ triggers mobile agent MPMA and creates m clones of it (D_L as input parameter);
Do
At each intermediate vehicle, each clone of MPMA computes neighbour vehicles and migrates to them;
Until neighbour vehicle = V_D
$VSMA_D$ triggers NDPF to compute n node disjoint paths;
$VSMA_D$ triggers MPE to assign priority (Eq. 1) to each node disjoint path;

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$VSMA_D$ communicates the priority list to $VSMA_S$ along the best path;
$VSMA_S$ determine the context of the information;
If context = Critical
Then
Communicate the information to V_D employing all paths in the list;
Else
Communicate the information to V_D along the best path;
End

III. SIMULATION MODEL

The proposed technique is simulated by taking Bangalore city map as an example [23]. The simulation is done using NS-2.34 [24] to test the efficacy of approach. We consider "N" number of vehicles moving in a fixed region of length "A" Km. and breadth "B" Km. We consider vehicle to move in number of lanes "L". Communication coverage area for each vehicle is considered as "VRAN" meters. At the start of the simulation, vehicles are uniformly distributed in lanes. We assume free flow movement of vehicles and congestions are ignored. Every vehicle is presumed to be equipped with a communication device and knows start position, start time of vehicle, route that it selects, and speed at which it travels. Safety distance of "R" meters between vehicles is assumed.

Figure 6.Bangalore City Map

A. Simulation Procedure

Simulation inputs are as follows: A= 5000m, B= 5000m, N= 50, VRAN = 300m, I= 20 Kmph, J= 60 Kmph, L= 2, R = 4 mts. Simulation procedure for proposed intelligent agent model is as follows.

Begin
- Generate VANET in given road length by placing vehicles uniformly.
- Maintain a data structure at each vehicle to store information as detailed by scheme.
- Apply mobility to nodes.
- Generate agency.
- Compute performance of system.

End

B. Simulation Inputs

The simulation input parameters are as below:

TABLE I. SIMULATION INPUT PARAMETERS

Simulation parameters	Values
Network simulator	ns-2.34
Simulation time	Simulation time: 600 seconds
Simulation area	5000m X 5000m
Number of vehicles	50/100/150
Communication range	500m
Speed	Minimum: 20 Km/hr., Maximum: 40 and 60 Km/hr.
Data type	Constant Bit Rate
MAC protocol	IEEE 802.11e EDCA based DCF
Safety distance between vehicles	3mts.
Available bandwidth	4000 Mbps
Road type	Free way

C. Performance Metrics

Some of performance metrics evaluated are as follows:

TABLE II.PERFORMANCE METRICS

Metric	Description
Packet Delivery Ratio (PDR)	It is the ratio of no. of packets reaching the destination to the no. of packets originating from the source node.
Path Discovery Time	It is the time taken to compute multipath to destination from source.
Transmission Time	It is the time spent by the data packet to reach destination from the source.
Communication Overhead	It is the amount of time spent in the dissemination of added information other than intended information. Overhead is due to the formation of multipath.

IV. SIMULATION RESULTS AND ANALYSIS

This section presents the results obtained during simulation. We compare results of proposed work with an existing multipath routing 2PR. The below mentioned figures are generated based on the simulation results.

Transmission Time

Figure 7 shows the Transmission Time evaluated for 2PR and MPMA protocols by increasing the number of paths between the source and destination in urban scenario. From the figure it is evident that the transmission time decreases with the increase in the number of paths. Nevertheless the transmission time of MPMA is lower than 2PR routing protocol. This is because as the number of vehicles increases and also due to the multipath between the source and destination the stability is more. Because of which retransmissions are minimized.

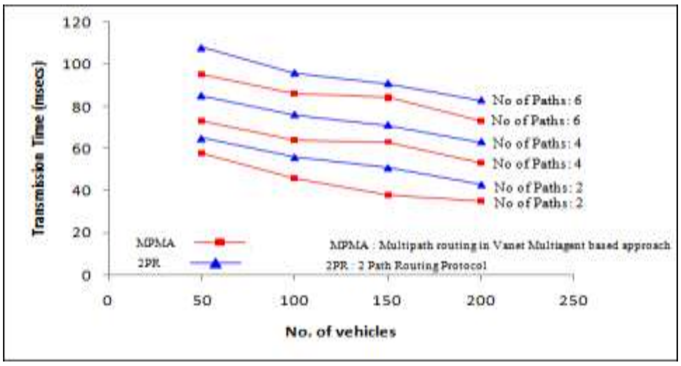

Figure 7.Transmission time V/s No. of vehicles

Packet Delivery Ratio (PDR)

Figure 8 shows the Packet Delivery ratio (PDR) evaluated for 2PR and MPMA protocols by increasing the mobility of the vehicles in the urban scenario. Number of paths is taken as the third quadrant. From the figure it is evident that PDR increases with the increase in the number of paths despite increase in the mobility of vehicles. The PDR of MPMA is more than 2PR routing protocol. This is because the intelligent software agents follow the defined trajectory, stability of the multipath.

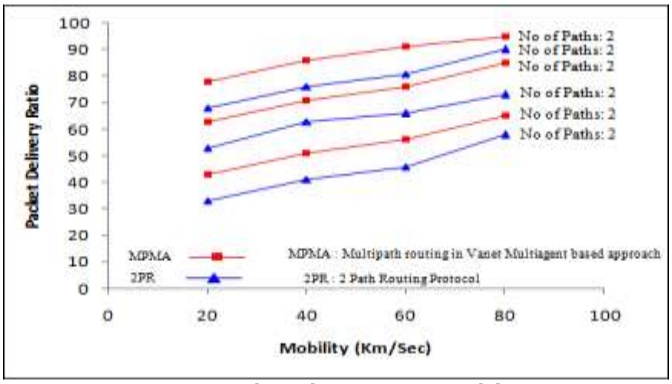

Figure 8.Packet Delivery Ratio V/s Mobility

Communication Overhead

Figure 9 shows the communication overhead evaluated for 2PR and MPMA protocols by increasing the mobility in the urban scenario. Due to the computation of multipath and other related activities the overhead increases with the increase in the mobility as illustrated in the figure. The communication overhead of MPMA is lower than 2PR routing protocol even at higher mobility. This is because the proposed work computes multipath employing intelligent agents which migrate carrying minimum information.

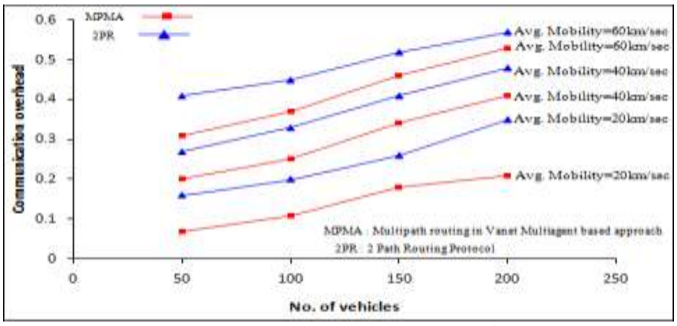

Figure 9.Communication overhead V/s No. of vehicles

V. CONCLUSION

VANETs unique features such as high speed nodes, continuously changing topology and etc. make them different from MANETs. With many of the dominant multipath routing protocols, all the computed paths are not operated. Therefore, in this paper, we have proposed an efficient multipath routing protocol called Multipath Routing in VANET: Multi-agent based Approach. The proposed approach works on all calculated multipath to transfer the information. The approach is tested by comparing its performances with 2 Path Routing (2PR). From the results shown in last section, we can notice that our approach performs better w.r.t transmission time, number of multipath computed, communication overhead and packet delivery ratio. The simulation results show better performance achieved by MPMA with multipath routing. In future work, we foresee the process of allocation of granularity which specifies the smallest unit of information allocated to each path.

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