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Agent based Dynamic Analytical Hierarchy Routing Protocol for Vehicular Ad hoc Networks

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Abstract: **Vehicular Ad hoc Networks (VANETs) has a large research potential due to the requirement of real-time traffic information and its various applications. QoS requirements are important for VANET applications to ensure safety and provide emergency services. Due to the highly dynamic environment the connectivity between vehicles degrades leading to a highly unstable network. Existing algorithms does not guarantee the stability in network during the routing process. They ignore the mobility constraints which are the most influential factors in VANETs. Routing in VANETs can be modeled as a multi-criteria decision making problem. To address the problem of stability by ensuring high throughput and packet delivery ratio with reduced delay, a routing protocol has been designed and implemented using agent based analytical hierarchy process. Experimental results show a significant improvement in achieving the network stability compared to traditional algorithms.**

Keywords: **Mobile agents, Analytic Hierarchy Process (AHP), Quality of Service (QoS), Stability.**

1. INTRODUCTION

Vehicular adhoc networks are a type of mobile ad-hoc network (MANETs) that aims to provide communications between vehicles (Jesus Tellez Isaac, 2008). 1) VANET differs from MANETs in which the mobility is constrained by the road topology. 2) VANETs provide direct communication among moving vehicles by exchanging traffic and safety information between the nodes. 3) The power constraint in VANETs is not a critical challenge, since vehicles have the continuous power using the long-life battery. VANETs are high speed vehicles which move in a structured or an organized fashion. The characteristics of VANETs are self-configuring, distributed, multi-hop channel with highly dynamic infrastructure. As the vehicle movement increases with velocity and distance, the communication between vehicles degrades tremendously. Different kinds of routing protocols have been proposed for VANET applications to ensure safety and reliable emergency services. The determination of nodes to forward the data dynamically possesses routing difficulty. Routing in VANETs is highly influenced by factors such as mobility, bandwidth, delay, packet delivery ratio, interest level, etc. Frequent disconnection of clusters and link failures are caused by high mobility. Since Vehicular Ad Hoc Networks is characterized by high mobility [13], it suffers from problems such as reduced network lifetime and link (connection) failures or breaks in networks. Routing in VANETs can be modelled as a multi criteria decision making problem. In this paper a new routing protocol has been proposed adapting mobile agent based analytical hierarchy process. The paper is organized as follows: Section II includes the relative study about different clustering algorithms. Section III describes the QoS parameters of the proposed system. Section IV describes the protocol Section V describes the implementation details of the proposed system. Section 6 depicts the performance results and analysis of the proposed system and Section 7 concludes the paper.

II. RELATED WORK

Extensive research is being carried out for routing the information in VANETs. Some of the relevant protocols and their limitations are discussed in this section.

B Ramakrishnan et al. [14] proposed a cluster based VANET model for simple highway communication. The system focused on creating clusters which should cover a certain geographical area. The limitation was that care has to be taken to maintain the size of a cluster. If the number of nodes in a cluster increases rapidly, it suffers from serious communication and routing overhead which degraded the efficiency.

Christine Shea et al. [5] proposed a similarity function derived to create stable cluster size in a VANET environment. It will not cluster vehicles moving in opposite directions which will degrade cluster stability. Since cluster change rate is directly proportional to cluster head duration and number of clusters, it suffered delays in case of lower mobility.

Zhang et al. [2] Proposed relative mobility as a metric which used the packet transmission delays to represent the logical distance between the nodes. Though it is suited for multi-hop scenarios, it suffered frequent cluster head changes. The algorithm avoided unnecessary re-clustering.

Maslekar et al. [12] proposed a direction based Clustering algorithm in which the clusters were formed when vehicles move in the same direction. Due to the frequent intersection of roads, the cluster changed frequently.

Morales et al. [1] proposed an adaptable Mobility-aware clustering algorithm in VANETs where clusters were formed based on both relative and final destination. They tried to follow the mobility pattern of the nodes in the network. The algorithm prolonged the cluster lifetime and reduced the global overhead. The performance degrades when the speed difference between the vehicles differs.

Kuklinski et al. [3] proposed a density-based Clustering algorithm that aimed to form stable long live clusters for stable communication. It combined metrics such as link quality, traffic conditions, etc. The algorithm avoided unnecessary re-clustering. The link quality becomes unstable since the nodes are selected based on past history which may change in the future.

Souza et al. [11] proposed a new aggregate local mobility clustering algorithm for VANETs (ALM). It is a beaconbased clustering algorithm that aimed to prolong the cluster lifetime using the aggregate weight. ALM weight can be calculated by the variation of the relative mobility over all the neighbor nodes. It provides stable cluster head thus avoiding cluster re-organization.

Su et al. [8] proposed a new metric based on vehicle density, link sustainability and link quality was defined. The clustering algorithm used the movement direction as the clustering metric. The algorithm defined the first node as cluster head which dominated the rest of the other nodes on its communication range.

Jacquet at al. [10] proposed a proactive, pure link state routing protocol which is best suited for large and dense networks. The basic idea was to form a cluster and to select Multi-point relays (MPRs). The main function of MPRs was to reduce the flooding of packets by minimizing the duplicate transmissions in the network. Due to its proactive nature, routes are known in advance. It involved recovery mechanism when the transmissions of packets are prone to errors. It is not suitable for applications which involve long delays.

Badis et al. [22] proposed a QoS based OLSR approach without any explicit reservation mechanisms that ensured the flow of data and avoided the interferences. But, it suffered from a back-off window strategy by which each node can't see the capacity of the data packet over flown. The distributed rule proposed satisfied the QoS constraints only when it was stored in a separate topology graph.

Omar Abdel Wahab et.al [13] designed a VANET QoS-OLSR protocol which considered mobility in order to provide a better trade-off between QoS and mobility constraints which hindered the efficiency of VANETs. The mobility metric involved both speed and distance in which both are responsible for ensuring the stability of the VANETs. It combined ACO in order to select the MPRs necessary for routing and a cheating prevention mechanism. Though it is efficient, it suffers link failures which are unavoidable.

Baras et al. [20] proposed a swarm intelligence inspired algorithm (PERA) which used ant agents to discover and to maintain paths in a dynamic topology. It exploited the inherent broadcast quality in wireless environment. It suffered from routing overhead than AODV in case of high mobility VANET scenarios.

Gunes et al. [19] proposed an Ant Colony-based Routing Algorithm (ARA)
in which ant agents were used. It suffered performance overhead due to the flooding nature of ants in the route discovery phase. It is not suitable for high mobile environments.

Di Caro et al. [18] proposed an Ant-Colony Optimization (ACO) algorithm which suffered routing overhead caused by the broadcasting of ant agents to the entire network. The sequences of random decisions to select the nodes possess difficulty for routing.

In summary, the routing protocols proposed have limitations which make them in efficient for VANETs. Therefore a Mobile agent based Analytical Hierarchy Routing protocol is used where routing is performed hierarchically.

III. QoS PARAMETERS

The QoS parameters selected to ensure the stability of the network are as follows:

1. Mobility (M): It defines the mobile nature of the Vehicular nodes.

$$Mobility\ (M) = \frac{Ratio\ of\ distance\ with\ respect\ to\ speed\,(Sd)}{Velocity(Vi)} \quad (1)$$

V_i defines the velocity of the vehicular node.

$$Velocity\ (V_i) = \frac{2*\ going\ distance * return\ distance}{Total\ time} \quad (2)$$

Where Total time = Going Trip+Return Trip

2. Bandwidth (B_i): It is the available bit rate or the consumed information capacity expressed in bits/sec.

3. Packet Delivery Ratio (PDR): The ratio of the number of data packets delivered to the destination.

$$Packet\ Delivery\ Ratio\ (PDR) = \frac{\sum No\ of\ Data\ Packets\ received}{\sum No\ of\ Data\ Packets\ Send} \quad (3)$$

4. End-to-End Delay (E_d): The average time taken by a data packet to arrive to the destination.

A. Vanet Environment

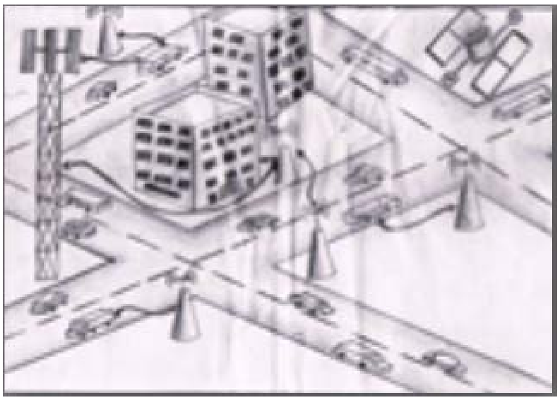

Fig 3.1 VANET Environment

The figure 3.1 depicts the VANET environment in which all the vehicles use a communication device known as Online Board Units (OBUs). These devices are used to communicate with the devices in other vehicles and also with roadside units. The roadside units are connected through the backbone network. The moving vehicles have access to internet through the backbone network. The movement of vehicles are limited by the road condition such as narrow or curved. High speed vehicles quickly form dynamic network topology and it requires real-time packet transfer. Due to the high mobility of vehicles the connectivity of vehicles degrades the QoS. Since QoS defines the quality measure to assess the performance of the network, it is a combination of several factors or criteria's, the difficulty arises when more than one criteria dominates. Hence routing becomes an inadvertent part in QoS which provides the best-effort network or service. Routing in VANETs can be modelled as a Multi-Criteria Decision Making problem (MCDM). There can't exist a unique optimal solution to an MCDM problem which are NP-hard in nature. Therefore, any MCDM problem can be solved in polynomial time.

B. Analytical Hierarchy Process Methodology

Analytic Hierarchy process is one of the methodologies of Multi-Criteria Decision Making (MCDM) problem which are NP-hard in nature. It consists of a finite number of alternatives, explicitly in the beginning of the solution process.

Step 1: Construction of Hierarchy Structure

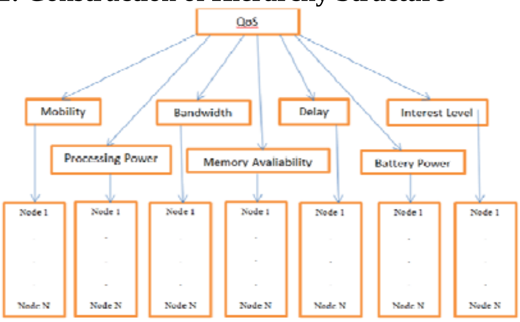

Fig.3.2 AHP hierarchy Structure for QoS selection

The problem can be defined a s finding the best alternative or finding a good set of alternatives. Since or problem is a MCDM problem, it is decomposed into a hierarchy of decision factors (i.e., criteria and alternatives). AHP is a structural technique for organizing and analysing complex decisions which can be carried out as follows: The figure 3.2 shows the analytic hierarchy structure which consists of goal of the decision i.e., "QoS" at the top level of the hierarchy. The next level consists of decision factors called as criteria for the goal. At the bottom level, there are N numbers of alternatives Vehicular nodes to be evaluated.

Step 2: Calculating local weights

Local Weight consists of two parts: the weight of each decision factor to the goal and the weight of each nominee to each factor. The procedure is as follows

1. Develop a Pairwise Comparison matrix for each criterion

The evaluation matrices are built through pairwise comparison of each decision factor with the topmost goal. The computation results are implemented by asking the questions: Which is more important? How much? Are presented in a square matrix A as

$$A= (a_{ij})_{nxn} = \begin{pmatrix} a11 & a12 \ldots\ldots & a17 \\ a21 & a22 \ldots\ldots & a27 \\ a31 & a32 \ldots\ldots & a37 \end{pmatrix} \text{---- (1)}$$

Where a_{ij} denotes the ratio of i^{th} factor weight to the

Number Rating	Verbal Judgment of preferences
1	Equally
3	Moderately
5	Strongly
7	Very
9	Extremely

2,4,6,8 indicates the medium value of above comparison

Table III-A Fundamental scale from 1 to 9

j^{th} factor weight and n is the number of factors. Each elements of a_{ij} is the ranking of judgements made by using the fundamental scale of 1 to 9 which can be used as the judgements of preferences designed and developed by Saaty [34]. The human judgements are used to determine the ranking of the criteria. All the diagonal elements in the pairwise comparison matrix are set to 1, so that the matrix can be solved using Eigen value and Eigen vector calculation.

2. The Eigen value equation can be written as

$$AW=\lambda_{max}W \qquad \text{-- (2)}$$

Where W is a non-zero Eigen vector and λ_{max} is a Scalar called as Eigen value. After normalizing the Eigen vector W, the vector element of W will be taken as the local weight of each decision factor approximately.

This can be denoted as:

$$W^T_j = \{w_1, w_2 \ldots w_n\} \qquad \text{-- (3)}$$

where $w_1, w_2, w_3, \ldots. w_n$ denotes the local weights of successful criteria's of eigen vector upon successive iterations.

3. Checking for Consistency

If every element in Eqn. (3) satisfies the equations $a_{ij}=1/a_{ij}$ and $a_{ik} * a_{kj} = a_{ij}$, then the matrix A is the consistency matrix. These results are often imperfect due to random people judgements. The judgement errors can be found by using Consistency Ratio (CR), which can be defined as the ratio of consistency index (CI) to Random Index (RI).

$$\text{Consistency Ratio (CR)} = \frac{\text{Consistency Index (CI)}}{\text{Random Index (RI)}} \qquad \text{-- (4)}$$

CI can be achieved by

$$CI = (\lambda_{max}-n)/ (n-1) \qquad \text{-- (5)}$$

$$\text{Where } \lambda_{max} = (1/n) \sum_{i=1}^{n} AWi/Wi \qquad \text{-- (6)}$$

The Random Index is as follows: The Consistency Test should satisfy the consistency index (C.I≤0.1) and the Consistency Ratio (C.R.≥0.1).

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

Table III-B Random Index

Step 3: Calculation of Global weights

. The global weight of each corresponding node can be achieved through multiplying the local weight with the corresponding parent. Hence, the matrix is of the form as,

$$W_{ni}=Wn_{i/j} * W_J \qquad \text{-- (7)}$$

Where the final weight of each alternative is calculated as follows:

$$W_{ni} = \sum_{(i=1)}^{n} W_{ni/j} * W_j \qquad \text{-- (8)}$$

Larger the final weight of the node, larger will be the probability of the node to be elected.

C. Mobile Agents

1) Agents with the ability to move from one system to another in order to process their tasks locally on that system are called Mobile Agents (Sharmila Anand, 2010).

2) Mobile agents work locally on a system and are independent of connection to the system. This improves the monitoring of systems or processes, which can be done locally [27].

3) Mobile agents are responsible for the collection and the processing of information in a centralized way.

IV. Mobile Agent Based Analytical Hierarchy Routing Protocol

The Mobile Agent based Analytical Hierarchy Process protocol consists of three phases: Initialization phase, Route Formation phase and Route Maintenance phase.

A. Route Initialization Phase:

The protocol uses Mobile agent and AHP methodology to choose the best node as a master node in the network. This can be achieved by computing the relative weights of the vehicular nodes using AHP methodology. The selection of the Master node can be as follows:

Each node ***broadcastshello*** messages to find its neighbours and maintains a neighbour list (contains neighbours of a node). The mobile agent preserves the collected information based on the decision factors or criteria's when it traverses from one node to another. The mobile agent contains a history of all nodes visited and maintains a database of all the visited nodes in the network. It updates the information as it traverses from one node to another.

B. Route Formation Phase

1. According to the local weights of the nodes, they are sorted in descending order and are stored in a ***Sort-List*** data structure that contains the Node-ID and weight field.
2. Usually, the first node is selected as the ***Backup node*** by the master node. The ***Backup node*** stores all the parameter values of the visited nodes.
3. The Master Node contains a list of IDs of all nodes which has the next highest capability in the network is either in the dominant set or has the neighbor of a node in the dominant set.
4. The communication between the nodes can be done by using dual power mode. The communication between the Master Node and the next highest capability node can be done using high transmission power and low transmission power is used for the communication within the dominant set.

C. Route Maintenance Phase

In order to reduce the overhead on frequent Master Node elections a recovery procedure has to be invoked in order to deal with link failures. The Route Maintenance Phase consists of two scenarios viz. Master node signs off or disappears, nearest highest capability node signs off or disappears and a New Node joins or leaves the network.

Scenario 1: Master Node Signs Off or Disappears

1. When the Master Node signs off, it nominates the next nearest highest capability node as the Master Node. This can be done by accessing the ***Master-table*** and sends a ***Master-Intimation*** packet to that node. The nominated Master Node the broadcasts it's ID as new Master Node throughout the network using the ***Master-Declaration*** packet.

2. When the next nearest highest capability node does not receive any ***hello*** packets within a specified time interval from the Master Node, then it may think that the Master Node has disappeared and it informs the mobile agent to check for the availability of that node. The mobile agent checks its database whether it has been recently visited and if visited, then it communicate with the informed node else it may check its availability by traversing throughout the network. If the mobile agent does not find the Master Node, then it confirms that it has disappeared and communicates with the ***Backup node*** to act as the Master Node. The ***Backup node*** then broadcasts its new Master Node ID throughput the network using the ***Master-Declaration*** packet. The procedure is same when the *next nearest highest capability node signs off or disappears and when a new node joins or leave the network.*

V. Implementation Details

Simulations are carried out by using mobile agents in a 1000x1000 flat topology. The highway topology is exploited to simulate the traffic suitable for VANETs in order to evaluate the performance of the models. The Random Waypoint model is used along with the simulation parameters with which the transmission range is varied from 50 to 300m and the maximum Speed of the vehicular nodes is about 20 m/s. By varying the number of vehicular nodes, transmission range and mobility of the vehicular nodes the performance metrics have to be evaluated. Table V-A shows the simulation parameters which are as follows:

Parameter	Value
Number of nodes	20, 30, 40,50,70,80 and 100
Transmission Range	150m
Topology	1000x1000m [Highway]
Packet size	1kb
Radio propagation	Log-narrow shadowing model
Link Bandwidth	2Mbps

Table V-A Simulation Paramters

The implementation is carried out in NS2 simulator employs C++ code to represent the parameters. The Highway topology is exploited to evaluate the performance of the VANET environment. The log-Narrow shadowing model has been used as the propagation model. Performance analysis and experimental results have shown better QoS than the existing protocols.

VI. Performance Analysis And Results

VANET is highly dynamic environment which is influenced by several factors such as packet delivery ratio, end-to-end delay and mobility, etc. It is important to analyse the results in terms of communication overhead, end-to-end delay, packet delivery ratio, throughput and percentage of stability, etc., Simulation experiments have been conducted to analyse the performance of AHP and DAHP routing protocols and a comparison between the existing VANET QoS-OLSR algorithm and our proposed protocols has been depicted. It is found that our proposed protocol performs better than the traditional approaches. By varying the number of vehicular nodes from 20 to 100, the simulation experiment for different QoS parameters have been carried out. Fig.6.1depicts the comparison between our proposed protocols with which the communication overhead increases with increase in the number of nodes and attains a constant level which favours efficient form of data communication. Fig.6.2 shows an improved percentage of stability between our proposed protocols. Fig.6.3 depicts the comparison graph for end-to-end delay which depends upon the number of times that the mobile agent traverses from one node to other during each packet transmission. Fig.6.4 depicts the increased packet delivery ratio. Fig.6.5 shows the comparison graph for average connectivity based on the fraction of connected node-pairs through single hop.

A. Communication Overhead:

Simulation experiments have been carried out by analysing comparison of AHP and DAHP protocols

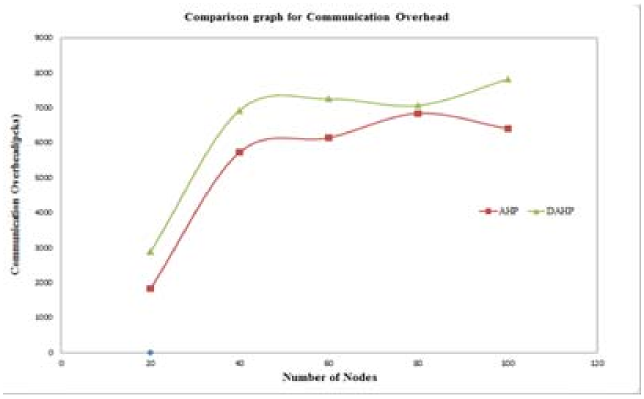

Fig.6.1 Communication Overhead

Communication Overhead increases with increase in the number of nodes and attains a constant level which favours efficient data communication.

By varying the number of vehicular nodes from 20 to 100, which shows that the communication overhead increases with the increase in the number of nodes and attains a constant level which favors efficient data communication.

B. Percentage of Stability

By varying the number of nodes from 20 to 100 in the log-narrow shadowing model, the simulation experiment has been carried by comparing the AHP and DAHP protocols. The graph shows that the link failures greatly reduced by minimizing the velocity of the vehicular nodes.

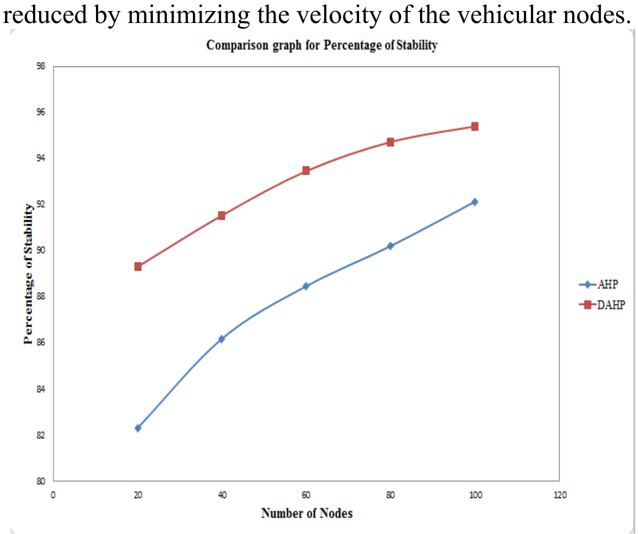

Fig.6.2 Percentage of Stability

Link failures are greatly reduced in our model by dividing the QoS value by the velocity ratio, thus providing higher stability.

C. End-to-End Delay

Simulation experiments have been carried out by varying the number of vehicular nodes in the vehicular environment the comparison between AHP and DAHP protocols have been carried out. The graph shows that the end-to-end delay had been considerably reduced which depends upon the mobile agent that traverses from one to another.

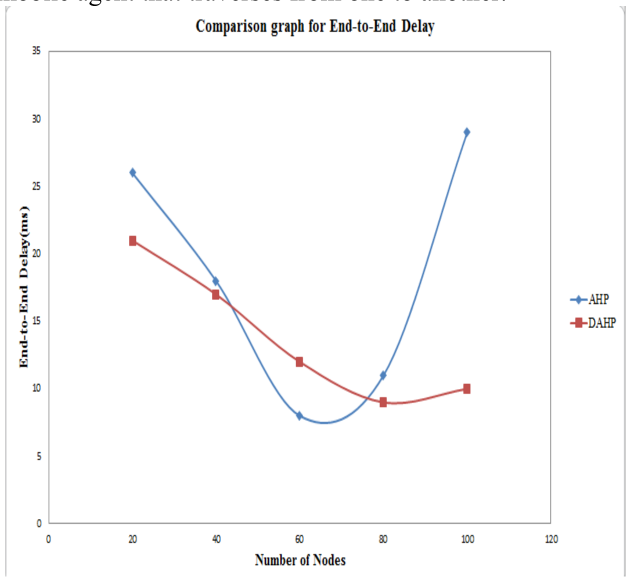

Fig.6.3 End-to-End Delay

It is inferred that the end-to-end delay has been significantly reduced which depends upon the ability of the mobile agent to traverse from one node to another during each packet transmission.

D. ***Packet Delivery Ratio***

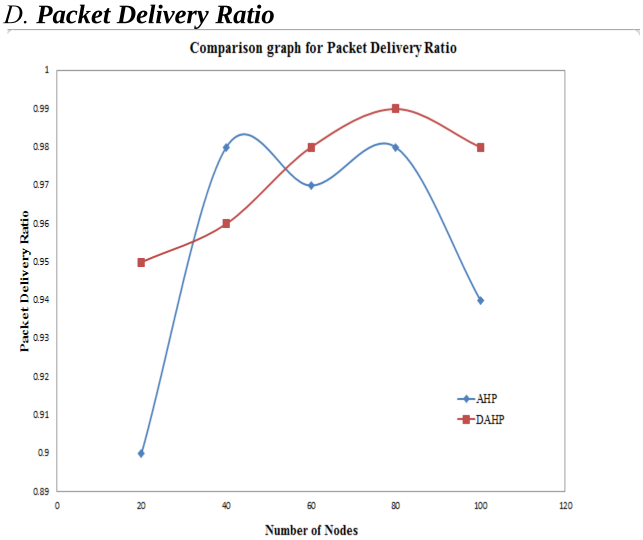

Fig.6.4 Packet Delivery Ratio

It is inferred that the packet delivery ratio increases with increase in the number of node, thus providing stability.

Since the packet delivery ratio is directly proportional to the velocity of the mobile agent, by limiting the velocity of the vehicular nodes the packet delivery ratio increases with the increase in the number of nodes.

E. Average Connectivity

Simulation Experiment has shown that the comparison between AHP and DAHP protocols achieves stability which provides efficient connectivity between the vehicular nodes in the VANET environment.

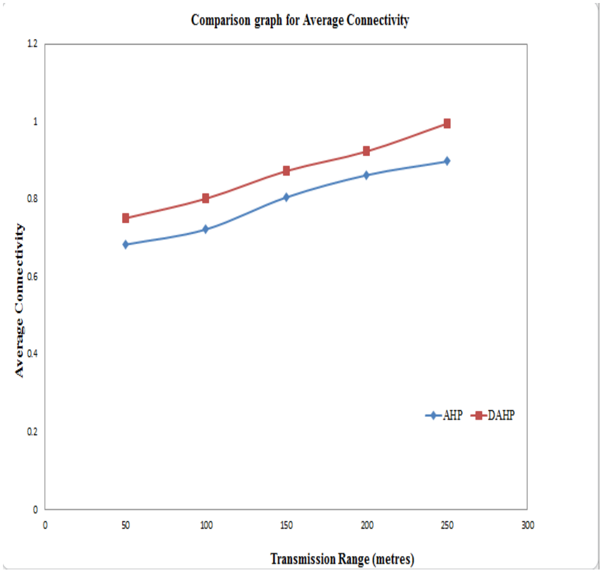

Fig.6.5 Average Connectivity

It depends upon the fraction of connected node-pairs in a single hop communication within a particular transmission range.

F. Comparison between different approaches

A comparative study has been presented between our proposed protocols AHP and DAHP and the existing VANET QoS-OLSR clustering approach. Our proposed protocols uses hierarchical approach instead of clustering with which the nodes are sorted in descending order from the highest to lowest relative weight. Simulation experiments have proved that by varying the number of nodes from 20 to 100 with respect to the transmission range from 50 to 250m. It has been observed that or proposed protocol performs better than the existing VANET QoS-OLSR protocol inspite of fewer differences.

Percentage of Stability: The percentage of stability can be calculated by using the formula:

Percentage of Stability (P_s)
= Number of nodes within a particular transmission range at a time (t_i) / Number of nodes within a particular transmission range before the time (t_i). -- (9)

In Vehicular ad-hoc network if the number of nodes approaches 60% and above than it is considered as stable [13]. It is inferred from the fig. VI-F the percentage of stability increases with increase in the number of nodes thus avoiding frequent disconnections. It is due to the fact increasing the distance factor by dividing the velocity proportionally converges to same speed before reaching the destination. Due to this the master nodes elected has higher stability thus facilitates efficient communication.

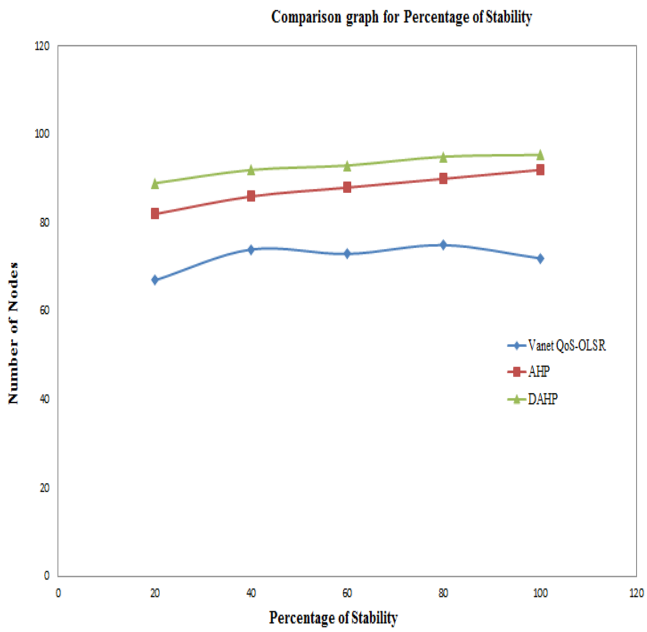

Fig.6.6 Percentage of Stability

Packet Delivery Ratio: The packet delivery ratio can be defined by the total number of packets received in the destination successfully to that of the packet sent. It is inferred from the figure.6.7 that the packet delivery ratio increases with increase in the number of nodes than the conventional approach thus favouring efficient data communication.

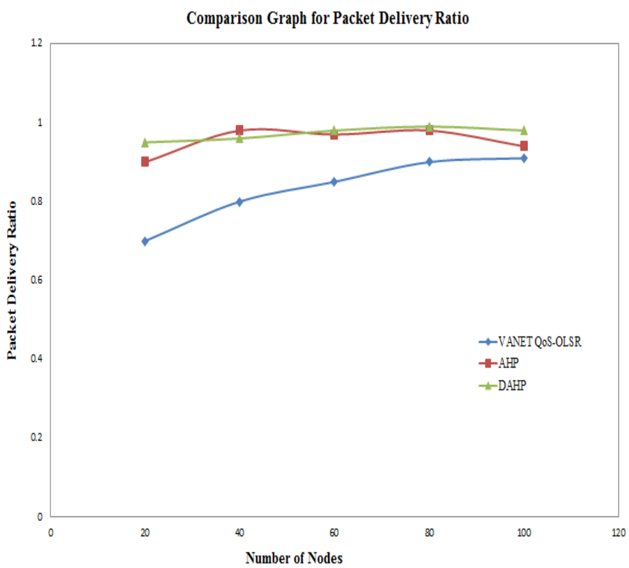

Fig.6.7 Packet Delivery Ratio

End-to-End Delay: End-to-End Delay can be defined by the average number of hops taken by a packet to reach the destination. It is inferred from the fig 6.8 as the mobile agent traverses from one node to other, the optimal choice of obtaining a best path can be done by the node having the highest relative weight which favours better QoS and low transmission rate. However, by using analytic hierarchy process link failures can be compensated by electing the subsequent master node which has the subsequent highest QoS value.

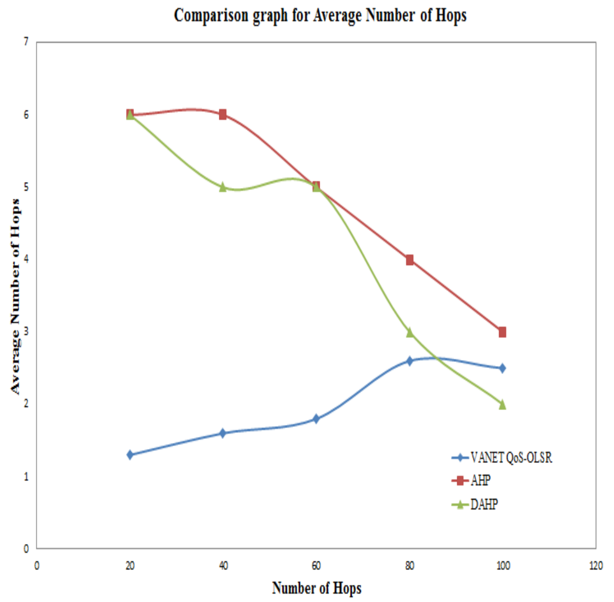

Fig.6.8 End-to-End Delay

Average Connectivity: The average connectivity can be defined by the number of connected node-pairs within a particular range with respect to the QoS value. It is inferred from the fig 6.9 that the average connectivity has been increased with respect to the transmission range with which can be justified by dividing with the velocity ratio makes the nodes to converge to stable speed. This eliminates the vehicular nodes violating the speed limits by electing the subsequent node which has the highest relative weight respectively.

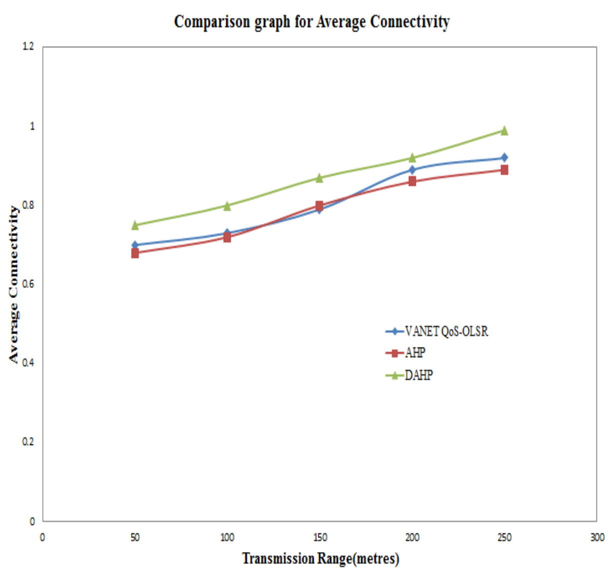

Fig. 6.9 Average Connectivity

VII. Conclusion

Thus the proposed protocol ensures the stability of the network by using mobile agents based on AHP methodology. To ensure the stability of the network, a new parameter mobility is included in terms of both velocity and distance ratios. The protocol elects the Master Node according to the global optimum value by using the analytical hierarchy matrix calculation with which the node with the highest capability is chosen. Simulation experiments have proved that our proposed system performs much better, thus providing stability facilitating the increase in the communication between the vehicular nodes by decreasing the delay in the VANET environment.

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