Emerging Trends in Computing: Reliability Design for A VANET with WUGFT Subject To Time and Cost Constraints

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Abstract**: *Reliable and quick communication is of prime importance in VANETs. Introducing clustering technique will ensure a robust data exchange in VANET. The emphasis on this work is to select the reliable cluster that make an appreciable communication in VANET with in a fixed time and cost. Hence this work considers the Cluster Head (CH) selection using Bully algorithm and Lamport time stamp. Furthermore, the traffic in the network is modelled using Weighted Universal Generating Function Technique (WUGFT). This will diminish the computation burden in reliability calculation. Reliability of VANET is defined as the probability of a successful delivery of data from source to destination. Reliability ratio has been considered to identify the efficient reliable cluster. A Simulation is carried out in NS – 2 with respect to delay, packet delivery ratio, and throughput and packet drop ratio. Simulation results indicate that our proposed method produces optimal results on the defined parameters.***

Index Terms**: *VANET, RSU, WUGFT, Bully Algorithm, Reliability, Clustering***

I. INTRODUCTION

The rapid growth of vehicle population in the recent past have given the way to the development of Vehicular Adhoc Network (VANET). VANETs are the special case of MANETs, roaming on the road that are offering multi-hop communication in the absence of wired network between vehicles-to-vehicles and vehicles to roadside units. They deploy various useful information in an efficient way. The vehicles participating in VANETs are equipped with on board units, road side units etc. to provoke excellent applications with the Intelligent Transport System. They encourage the comfort of driving by exchanging the information like vehicle's speed, location, direction and driver's behaviour. They will support to provide a better road experience for the drivers as well as passengers.

Nodes of VANET will experience fast node mobility and frequent topology changes. Hence in dense network scenarios, periodic updating of vehicle movement, monitoring traffic flow and topological structure changes is impossible and will result in a hectic congestion in the network. This situation can be mended by introducing clustering technique in VANETs. Clustering will organise the nodes in various crowds which in turn will diminish the effect of congestion in the network. Stable maintenance of clusters is a promising issue in clustering. Electing a Cluster Head(CH) will increase the stability of clusters. This work applies bully algorithm and Lamport time stamp to elect the CH. All type of data exchanges are ensured via CHs.

Reliability is a birth to death process and is concerned by everyone. It has a promising role in the performance measure of a system. Network reliability will enhance a reliable and dependable data transmission in a network. Network reliability related issues have been incited by many authors using numerous methods. Universal generating Function Technique(UGFT) exploits other related methods. They are good candidate to model the performance distribution for a wide range of network with changing topology. UGF has a considerable role in finding out the expected capacity for each transition involved in the network. It is based on the definition of u-function of multistate nodes and composition operators defined over u-functions. Meena and Vasanthi [2016] have evaluated the reliability of MANET using UGFT. The highlighting contribution of this paper is on obtaining the reliable and dependable cluster for a quick communication.

II. BACKGROUND

The researchers of network reliability field have come across a plenty of methods and algorithms for reliability evaluation. These methods are based on graph theory and Boolean algebra. Jin-Jia chang et al (2012) have explained STAR (Shortest path based Traffic-light Aware Routing) for VANETs with the traffic light consideration which is an intersection based routing protocol in dense areas, where the traffic density is high, traffic lights exist at intersections and vehicles may halt and go. Zhengming li et al (2013) has proposed three algorithms for message dissemination in VANET. The three algorithms are distance based gradient algorithm, privacy preserving and incentive centred cash in algorithm. Incentive centred architecture is proposed to encourage the SPs to set reasonable cost and effect requirements for advertisement dissemination. Ziahmoud Hashem Eiza & Qiang Ni (2013) have proposed a MOvement Prediction-based Routing algorithm (MOPR) that predicts the future position of a vehicle and searches for a stable route. Uma Maheswari and Rajeswari [2015] portrayed the ongoing patterns in computer science

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Which was in light of reliability computation of VANET with RSU utilizing UGFT. Rajeswari et al [2018] have demonstrated the dissemination reliable information to the ongoing vehicles via road side unit using UGFT. Reliable Fuzzy Reputation system was defined in VANET to segregate selfish nodes to transmit the information among vehicular nodes in the presence of selfish nodes.

The development of VANET in clustering environment will support the reliable communication in a dynamic scenario. The main aim of clustering is to organise vehicles into homogeneous crowds with some common characteristics. Each cluster will have one cluster head like neighbourhood, moving in similar direction and speed etc. Many surveys and research has been done using clustering and cluster head election algorithm.

Fan et al (2011) used a utility based cluster formation technique. Utility function is used as parameter to perform clustering. Ahamed et al (2011) have proposed LICA: Location Improvement with Cluster Analysis used to improve the accuracy of GPS device. Tian et al (2010) demonstrated a clustering method based on Euclidean distance for which the position and the direction of vehicle are used as parameters to form a cluster. A vehicle with minimum distance parameter is elected as a cluster head. Remaining nodes are used to form a cluster. Santos et al (2003) presented CBLR (Cluster Based Location Routing) algorithm to perform clustering in VANET. Bali et al (2014) defined the taxonomy, challenges and solutions of clustering in vehicular adhoc network. Rajeswari et al [2018] have presented VBRCP (A Reliable Vehicle Based Reliable Clustering Protocol for transmitting road safety information between nodes.

Meena and Vasanthi (2015) have considered the Cluster Head Gateway Routing Protocol in MANETs. Meena et al. [2015] designed the reliability of MANET by using Reliable Cluster Forming Protocol in which Universal Generating Function Technique was used to assess the reliability of MANET. Meena [2017] have applied RCFP with improve parameters for VANET. While applying UGFT, the length of u-function will be considerably long if the number of nodes increases. . Meena [2017] have modelled WUGF for MANETS. This work introduces the WUGFT to VANETs to diminish the computation burden. Random weights are considered according to the hops and u-functions are generated to obtain the reliability of the VANET. This work integrates the performance of VANET under WUGFT.

III. PROBLEM DESCRIPTION

VANET consists of group of vehicular nodes equipped with OBU – On Board Units, Roadside Central Processing Unit – RCPU which consists of RSU – Road Side Unit, Advanced junction with high speed processor to store and retrieve the data. This Roadside Central Processing Unit is made to broadcast alert messages to all the vehicular nodes in a particular roadside i.e., four-way road so as to disseminate the information to a set of all vehicles. If all nodes which are participating in VANET receive the message at a time, then strongly there will be traffic congestion. In order to avoid this, nodes are grouped into clusters with a CH- Cluster Head and some nodes as members for which a CH is elected based on bully algorithm. It is assumed that the CHs will receive alert message directly from the RCPU at a time. They will ensure the trustworthiness of the received information among its members. The main aim of this paper is to avoid the delay in delivering the traffic alert message to the desired destination node. Reliability of VANET is calculated by considering the clarification with a member node which is done at a maximum of two times only. That is, a node can participate twice in a transition within a two hops. Also it is considered that a successful transition will be done within a maximum of four hops. Once the clarification gets over, the CH will relay the information to the nearest RSU. It will in turn alert the ongoing vehicles accordingly. The time taken to receive data from the RCPU, clarification among the member nodes, out sourcing the data to RSU, receiving data at the destination everything should occur within a short while. Examining all these functioning that occur only through clusters, we thereby conclude which cluster is more reliable in transiting the information. The parameters reliability, economy and rapid delivery are having vital role in choosing the Reliable cluster.

IV. PROBLEM MODELLING USING WUGF

A. Preliminaries

The tremendous growth of Ad Hoc Network led the era up. In ad-hoc network, the network topology frequently changes due to random nature of nodes. The stability of ad-hoc networks rely on the stability of individual nodes. VANET, which is a kind of ad-hoc network, has the characteristics that are similar to MANETs. Mobility of nodes in MANETs is random whereas the mobility of nodes in VANETs is not completely random. That is the traffic environment where the vehicles move is predictable and have some restriction.

Irrespective of the vehicle location, VANETs have the ability to make the communication in any traffic dense environment. The increase in number of nodes in VANET will perturb the network stability. Nodes of VANET will face serious scalability, connectivity and route maintenance problem. This can be rectified by introducing clustering process. Literally, clustering means dividing the broad area into small area to persuade an effective communication. These clustering processes will mitigate the effect of overhead and delay in delivery. Using this process, the coordination between nodes can be improved. Cluster size is not a fixed one due to the speed and density of nods. Maintaining the cluster stability is a challenging task. Selecting the Cluster Head (CH) from members of a cluster and accounting all signalling via them will prolong the stability of that cluster. CH selection algorithms are abundant in literature. The performance measure of clustering algorithm includes maintaining the cluster stability and providing better communication within a cluster.

B. Bully Algorithm

Bully algorithm outperforms other related clustering algorithms. It is the fastest among cluster election algorithms since it will reduce the election time and message overloading. In bully algorithm, the nodes that comes nearer to each other's, will form a cluster and numbered from lower ID (starts from 1) to higher IDs according to total members of that particular clusters.

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At start, the node with higher-up Id takes the lead. If the performance of that node is crashed, then any one of the members which notices this as first will send ELECTION message to all the members that possess higher ID than it. In bully algorithm, any node may send an ELECTION message at any moment to the nodes which are in higher-ups than that node. Once a particular node receives an election message, it will reply with OK message to reveal that it is alive and will take over. The receiver then holds an election, unless it is already holding one. Eventually, all nodes give up except one, and that one is the new coordinator. It announces its victory by sending all nodes a message telling them that starting immediately it is the new coordinator. If a process that was previously down comes back up, it holds an election. If it happens to be the highest-numbered process currently running, it will win the election and take over the coordinator's job [Pramodh 2017].

Lamport (1978) defined a relation called happens-before. The expression x-y is read “x” happens before “y” and means that all processes agree that first event “x” occurs, and then afterward, event “y” occurs. This happens-before relation can be observed directly in two situations: 1) If “x” and “y” are events in the same process, and “x” occurs before “y”, then x-y is true. 2) If “x” is the event of a message being sent by one process, and “y” is the event of the message being received by another process, then x-y is also true[Pramodh 2017].

C. WUGF and Flow Monitoring

This work concentrates on WUGF in order to mitigate the length of U-function while addressing about the flow in a network. In a VANET, suppose there are more number of nodes, then the probability computation for the traffic within the network will become more cumbersome. Hence, introducing WUGF will shorten the time of computation process. That is for each PUGF, the hops are identified and based on it, and random weights are allotted. Hence Path UGF becomes WPUGF. The information may reach the target in 2 (or) 3 (or) 4 (or) n steps. Based on this, weights 2 (or) 3(or) …. or (n) will be allotted so as to reduce the length of u-function in the path UGF.

The flow of information from node n to the neighbouring nodes j,k,l,… reaching the terminal node D in i steps is denoted by $n_i P_{n:j,k,......D} X^{D}_{(c,d)}$. In this, the exponent and coefficient of X denotes the state and the probability of flow of information from node n to node D respectively. Also, the letters given in the subscripts denote the total cost and time for a particular transition. The notation Pi:φ denotes the non-working state of a PUGF and its probability has no impact in reliability calculation. The transmission probabilities of working states are considered in reliability calculation.

Definition 1

The Individual UGF for the source (CH) is defined as a polynomial in X as $U(S) = \sum_{N \subseteq \theta_S} P_{S:N} X^{D}_{(c,d)}$ where $P_{S:N}$ is the probability that the set of nodes $N \subseteq \theta_S$ receiving information directly from source node S. For a CH, $u(S) = U(S)$.

Definition 2

The weighted individual UGF for neighbouring nodes is defined as a polynomial function of X by $u(n_w) = \sum_{N \subseteq \theta_S} n_i P_{n,N,D} X^{D}_{(c,d)}, N \subseteq \theta_n$ where $P_{n:N,D}$ is the probability that the set of nodes $N \subseteq \theta_n$ receiving information directly from node n and transmits it within the group (only one time repetition is permitted) and finally reaches the destination D. Here n_i represents the step size that the information initiated from node n is reached D in i steps. The inclusion of n_i will makes the reliability calculation easier.

Definition 3

The weighted path UGF is defined using the node UGF and the composition operator as $U(n_w) = U(S) \otimes u(n)$, n = 1,2,3,…..,t, $t = |N - D|$. $U(n_w)$ can be also defined as a polynomial function of X. $U(n_w) = \sum_{N \subseteq \theta_S} n_i P_{S:n,N,D} X^{D}_{(c,d)}, N \subseteq \theta_n$.

Definition 4

The reliability ratio between clusters is defined as $RR = R_{CL_i} / R_{CL_{i+1}}$, i=1,2,……. If RR >1, then R_{CL_i} is more reliable than $R_{CL_{i+1}}$ otherwise R_{CL_i} is reliable.

D. WUG Algorithm

Step 1: Define the UGF for each cluster head.

$$U(S) = \sum_{N \subseteq \theta_n} P_{n:N}, X^{N}_{(c,d)}$$

Step 2: Define the WUGF for all neighbouring nodes except the source in each cluster.

$$u(n) = \sum_{i} n_i P_{n:N,D} X^{D}_{(c,d)}, N \subseteq \theta_N .$$

Step 3: Composite the path WUGF U(n) as a polynomial in X, $U(n_w) = u(S) \otimes u(n_w)$.

Step 4: Compute the reliability of each clusters.

Illustration

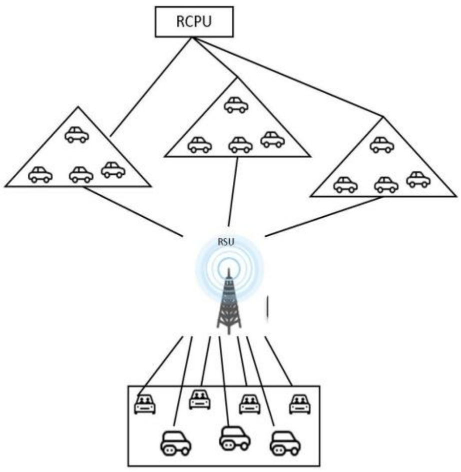

Figure 1.VANET Environment

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Table 1. The Transmission Probabilities of the VANET Corresponding to Random Weights.

Clusters	CHs	Random Weights		
		2	3	4
CL I	4	0.02	0.1	0.001
CL II	8	0.02	0.01	0.002
CL III	12	0.02	0.01	0.001
Cost($)	--	0.1	0.15	0.25
Time(sec)	--	0.2	0.3	0.4

VANET is a special kind of MANETs which are experiencing continuous structure changes with high peripatetic nodes. Reliability calculation is a performance index for the transition ability of a network. When the nodes are huge in numbers, obtaining reliability is a challenging task. For example, consider the network given in Fig. 1.

It has totally 22 nodes including source and destination nodes which are divided in to three clusters. Cluster I (CL-I) is having nodes numbered from 1 to 4 and the nodes 5, 6, 7 & 8 are attached to CL-II. CL-III contains the nodes 9, 10, 11&12 as its members. Among these 22 nodes, 13 nodes which are placed above RSU will receive and pass the information while the nodes down to RSU will receive the alert message for experiencing a better driving environment. The problem taken into account here is RCPU will disseminate the information to send and receivable nodes and these nodes will in turn send it to the nearest RSU. This RSU will pass the message to all the nodes that comes under its coverage area. Without any doubt, this will lead to a hectic traffic in the network and messages will not be conveyed in an efficient manner. Hence to make the communication effectively, the nodes that are capable of sending and receiving (12 nodes) are combined together to form clusters. There are three clusters present in this network. Due to the varying nature of nodes, the maximum number of clusters can't be predicted. After clustering, CH is selected using bully algorithm.

In bully algorithm, the node with highest ID will be elected as CH. If it crashes, then any node which identifies this as first will send an election message to the nodes which are big to it. The next higher-up's node that receives the election message will send an ok message and will lead the cluster. If the crashed node comes back then it may hold the election. If this situation occurs, then the node that is currently big will be the new coordinator.

In this example, (Fig. 1), each cluster is having four nodes. At the time of study using bully algorithm, the nodes 4,8,12 are treated as cluster heads (CHs) for CL-I, CL-II CL-III. These nodes will coordinate all the communication in that particular cluster. After CH election, RCPU will relay the message at a time to the CHs 4,8 and 12. After making local communication, these heads will send the information to RSU which in turn outsource it to all nodes that are in its coverage area .RSU and the nodes above RSU are performing in one-to-many.

Transition probability, transition time and transition cost are given in table 1. These data will support to choose the reliable cluster. These are considered based on the hops taken by a message in a transition. Reliability ratio has been proposed in order to identify the reliable cluster.

Table 1 summarizes the Random Weights and the corresponding Transmission Probabilities of the VANET. These weights are assigned based on number of the hops to reach the destination from CHs. Also it gives the required cost and time to reach the target form source. The algorithm proposed in subsection C can be applied to the above network (Fig.1) with the data given in the Table 1 is as follows.

E. UGF and Reliability Calculation for CL-I

The node UGF of CL-I (headed by node 4) and member nodes 1,2 and 3 are obtained by considering all possible communications that receives information directly from the nodes.

$$u(4) = U(4) = P_{4,1}X^{1} + P_{4,2}X^{2} + P_{4,3}X^{3} + P_{4,\{1,2\}}X^{\{1,2\}} + P_{4,\{1,3\}}X^{\{1,3\}} + P_{4,\{2,3\}}X^{\{2,3\}}P_{4,\{1,2,3\}}X^{\{1,2,3\}}$$

$$u(1) = [P_{1:4} + P_{1:2,4} + P_{1:3,4} + P_{1:2,1,4} + P_{1:3,1,4} + P_{1:2,3,4} + P_{1;3,2,4} + P_{1:\{2,3\}::\{\phi,4\}} + P_{1:\{2,3\}::\{4,\phi\}} + P_{1:\{2,3\}::\{4,4\}}]X^{4}$$

$$u(2) = [P_{2:4} + P_{2:1,4} + P_{2:3,4} + P_{2:1,2,4} + P_{2:1,3,4} + P_{2;3,2,4} + P_{2:\{1,3\}::\{\phi,4\}} + P_{2:\{1,3\}::\{4,\phi\}} + P_{3:\{1,3\}::\{4,4\}} + P_{2;3,1,4}]X^{4}$$

$$u(3) = [P_{3:4} + P_{3:1,4} + P_{3:2,4} + P_{3:1,3,4} + P_{3:1,2,4} + P_{3;2,3,4} + P_{3;2,1,4} + P_{3:\{1,2\}::\{\phi,4\}} + P_{3:\{1,2\}::\{4,\phi\}} + P_{3:\{1,2\}::\{4,4\}}]X^{4}$$

The WPUGF of CL I for nodes 1,2 and 3can be obtained as follows:

$$U(1_w)=U(4) \otimes u(1_w) = \sum_i 1_i\, p_{4:1,N::4} X^{4}, N \subseteq \theta_1$$

$$U(1_w) = 4[1_2 P_{4:1,4} + 1_3 \left(P_{4:1,2,4} + P_{4:1,3,4}\right) + 1_4 \begin{pmatrix} P_{4:1,2,3,4} + P_{4:1,2,1,4} + P_{4:1,3,1,4} + \\ P_{4:1,3,2,4} + P_{4:1,\{2,3\}::\{\varphi,4\}} + P_{4:1,\{2,3\}::\{4,\varphi\}} + P_{4:1,:\{2,3\}::\{4,4\}} \end{pmatrix}]X^{4}$$

L

ikewise, $U(2_w)$ & $U(3_w)$ can be formed.

$U(2_w) = U(4) \otimes u(2_w) = \sum_i 2_i\, p_{4:2,N::4} X^{4}, N \subseteq \theta_2$ & $U(3_w) =$

$U(4) \otimes u(3_w) = \sum_i 3_i\, p_{4:2,N::4} X^{4}, N \subseteq \theta_2$

In reliability calculation via CL-I, all the successful transmissions via 1,2 and 3 are combined. Totally there are three possibilities with weight 2, twenty one possibilities with weight 3 and six possibilities with weight 4.

R_{CL-I} via nodes 1,2 & 3 are calculated as $R_{CL\,I} = U(S) \otimes u(4) = P_{S:4,D} = U(1_w)+U(2_w)+U(3_w)$

$R_{CL\,-}$ =4[3x0.03+6x0.06+21x0.01] = 0.924

In the same way, the reliability, required cost and time via CL-II & CL-III are obtained and listed in table 2.

Table 2: Reliability of Various Clusters.

CLs	Reliability	Cost (&)	Time
CL I	0.936	22	39.6
CL II	0.768	22	39.6
CL III	0.888	22	39.6

Hence the reliability of each cluster is listed in table 2. Cluster I achieves the target with a reliability of 0.936. CL-II and CI-III achieve the target with a reliability of 0.768 and 0.888 within 39.6 seconds and a cost of 22$ and . According to the definition 4.3, it is clear that CL-I is more reliable than CL-II and CI-III.

V.RESULTS AND DISCUSSIONS

Network Simulator – 2 is used to simulate the performance of VANET using Reliable Cluster Forming Protocol. Vehicular nodes are taken randomly ranges from 10 nodes to 100 nodes with the average speed ranges from 50km to 100 km. Figure 2 denotes the average packet delivery ratio of our proposed technique in which x axis represents no. of nodes and y axis denotes the packet delivery ratio in percentage. It is observed that the packet delivery ratio gets increased when the number of nodes in simulation area increases. Figure 3 represents the packet delay ratio which is measured with respect to node velocity and end-to-end delay in ms. End-to-end delay of the packet is represented as the total amount of time it takes to reach the destination. It is noticed that the delay is getting decreased in the proposed technique which is seen in the figure. Figure 4 denotes the throughput which is represented using node velocity. Throughput is the total number of packets that are successfully sent and received by the corresponding nodes.

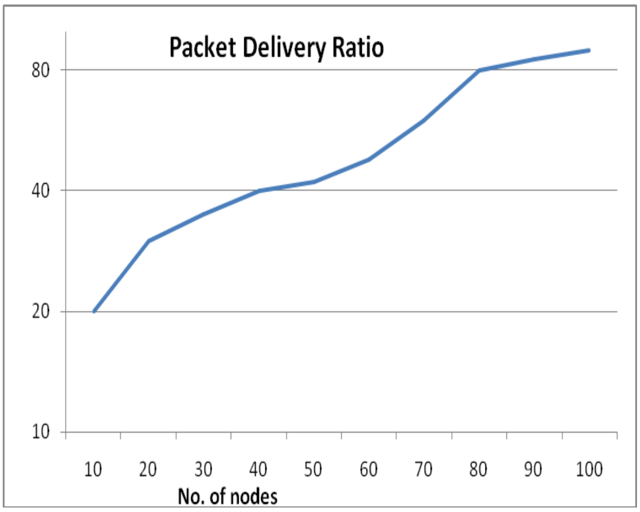

Figure 2. Packet Delivery Ratio

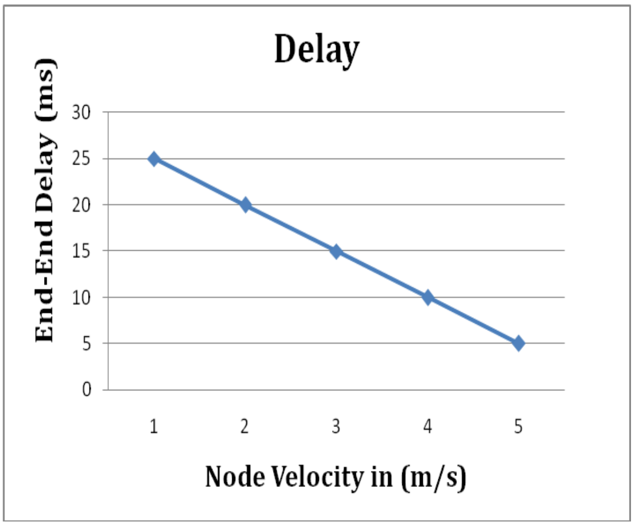

Figure 3. Delay

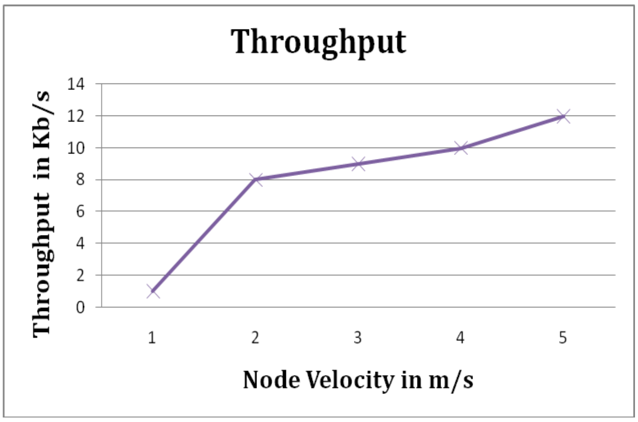

Figure 4. Throughput

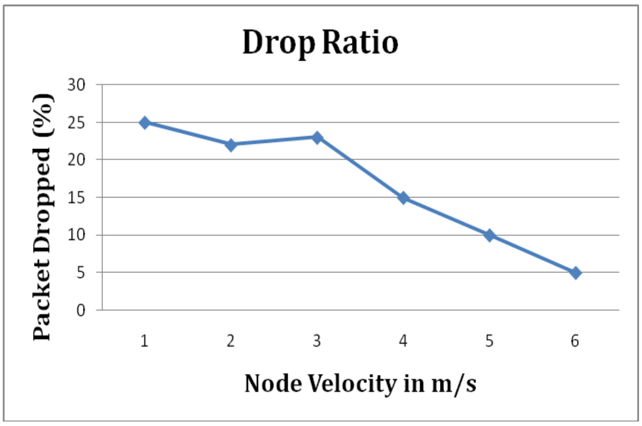

Figure 5 represents the packet drop ratio which is calculated using node velocity versus percentage of packets that are dropped.

It is assumed that all the packets that are sent by the source node will not be received by the receiver node successfully. It is observed that some of the packets are dropped in the middle of the data dissemination process because of path failure or node failure etc. In the proposed method, packet drop is getting decreased which is clearly shown in the figure. Simulation results proved that the proposed method performs well with respect to packet delivery, drop, throughput and delay.

VI. CONCLUSION

It is a difficult task to analyse the performance of highly reliable network. Some new methods should be adopted to follow these issues. This study examines the reliability of a VANET in a WUGF paradigm. WUGF has been used in order to ease the reliability calculation. Random weights based on the hops between the source and destination has been included in reliability calculation. An illustration of this technique has been proved in a traffic environment. The effectiveness of the algorithm discussed in 4.4 is proved by the mathematical modelling of the traffic inside the network (Figure 1) given in section 4. The numerical computation shows the successful implementation of this novel technique.

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