Performability of VBRCP in VANET using UGFT

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Abstract: A reliable Vehicular Based Reliable Clustering Protocol (VBRCP) for transmitting road safety information between vehicular nodes is presented in this paper. Transmission range of vehicular nodes are said to be identified during phase-I of VBRCP. Nodes are grouped to form a cluster based on this transmission range of vehicular nodes. The parameters like Degree, Degree In Difference, Sum of Degree, Battery power, Node movement and Combined weight are used to elect the cluster head. The reliability of transportation system is considered as the probability of successful delivery of information from a source vehicle to the destination vehicle. This is attained by using UGF (Universal Generating Function). Node UGF of a member node / cluster head and link UGF are used to define the reliability of VBRCP. Algorithm is proposed in UGF in order to calculate the link reliability which represents the successful delivery of traffic information between the ongoing vehicles on the roadside. Proposed protocol is compared with some other existing protocols. Simulation results show that VBRCP outperforms other protocols in terms of delay, packet delivery and throughput.

Index Terms: UGF, VANET, VBRCP, Transmission Probability.

Acronym:

CH_i	*Cluster Head i*
D	*Destination*
$u(i)$	*UGF of node i*
$u(CH_i)$	*UGF of Cluster Head i*
$LR_{i:D}$	*Link Reliability Between i & D*

I. INTRODUCTION

VANET is considered to be a subset of MANET where vehicles on the road that are moving are considered as nodes. In VANET, each vehicular node is made to act as a relay for transmitting traffic information. Information [11][13] or data transferred will be Traffic safety / Road conditions, Advertisements, Internet 3G/ 4G, Multimedia content etc. In an everyday life, we confront numerous troubles to achieve our goal on time because of road accidents, traffic jam and superfluous stopping of vehicles out and about. Traffic alert messages ought to be conveyed to vehicular nodes when an accident or crisis circumstance happens. With the goal that the vehicles that are coming towards the accident spot would take another path to arrive the place at the earliest. This diminishes undesirable activity and congestion in the street.

Routing [13] is the method of sending the information from originating node to receiving node through number of neighbouring nodes in a network. Topology discovery helps to perform routing effectively in VANET. Topology may be formed in an adhoc manner which makes it difficult to find the reliable path. Typically topology discovery attempts to find the location information for the source, destination and all intermediate vehicles across a network. Multiple network hops are required for one node to transmit the traffic information to other ongoing vehicles. As in MANETs, effective data delivery in VANETs depends on finding a reliable path from any node to collection of any other nodes. Clustering protocols have been widely used to route the messages in VANET. Vehicular nodes are grouped into clusters which will form a cluster structure. Researchers use speed of a vehicle, density, transmission efficiency, cluster stability as parameters to form a cluster structure.

Reliability [8] [9] [10] is a birth-to-death process and is concern of everyone. It deals with systematic analysis of product failures and tries to address the issues. Reliability evaluation for a network from the source node to the sink node has attracted many researchers' attention in the last several years. The reliability of a network is the probability of connectivity from the source to the destination. In traditional reliability, both the system and its components are allowed to take only two possible states: either working or failed. Also, systems with different levels of performance (more than two) are known as Multi State Systems (MSS). In a multi-state system, both the system and its components are experiencing more than two possible states, like completely working, partially working, or partially failed and completely failed etc. A multi-state system reliability model provides more flexibility for modeling many real-world systems. These systems are modeled as networks for executing their reliability conveniently.

This paper proposes a Reliable Clustering Protocol - VBRCP whose aim is to transmit the traffic alert information [12] from any vehicle to any other vehicle in the roadside without missing the reliability. This protocol is formed by grouping the vehicles that enter into the particular road at particular instance of time. Nodes that lie in a particular coverage area are grouped together to form a cluster. Cluster head[11][12] is chosen for each cluster by examining different parameters and after that correspondence among vehicular nodes is accomplished which are explained in Chapter 3. Various clusters are formed and example cluster formation is given in this paper to show that the reliability is accomplished while exchanging the data from a source vehicle to goal vehicle.

Simulation is done in NS- 2 for various parameters in which more than 20 iterations were taken with various number of nodes. Simulation area is set up with 50 to 200 nodes move in 2000 meter *2000 meter square region for 100,200 and 300 seconds simulation time. To simulate this, vehicle speed ranges from 50 km/h to 80 km/h with an average speed of 50 km/h. Simulation results prove that proposed protocol VBRCP outperforms other existing protocols according to various parameters mentioned in this paper.

II. RELATED WORK

Salhi et al. [2] proposed a position based clustering algorithm where the cluster structure is determined by the geographic position of the vehicle. Hash function based on the estimated travel time is used to determine the priority for vehicle to elect the cluster head. Vehicle which has the longer trip is given a higher priority and elected as a cluster-head, thereby; the stability of the system is improved. Wang et al. [3] defined a cross-layer algorithm which follows position based clustering technique. This algorithm collects the geographical information to find the location of vehicles and disseminate the information. Fan et al. [5] used a utility based cluster formation technique. Utility function is used as parameter to perform clustering. Clustering is done based on the destination which uses current location of the vehicle, speed and vehicle density. Farhan et al. [4] proposed LICA: Location Improvement with Cluster Analysis used to improve the accuracy of GPS device. This technique helps drivers to reach their destination safely by calculating the distance, time-of-arrival and Received Signal Strength (RSS). Multiple measurements are used to find the accurate distance between the source and the destination vehicle to achieve a better performance. Fan et al. [6] presented a lane-based clustering algorithm based on the availability of lane information. This algorithm requires an assumption that each vehicle knows its exact lane on the road by using some lane detection system. Cluster head is elected according to the lane information and hence the stability of the system is increased. Zhang et al. [7] designed a multi-hop clustering scheme for representing N-hop mobility. Each vehicular node broadcasts their aggregate mobility value in the N-hop mobility. Node with smallest aggregate value is chosen as a cluster head and other nodes are called members of a cluster.

Bali et al. [1] defines the taxonomy, challenges and solutions of clustering in vehicular adhoc network. Comparative analysis of various clustering protocols in vehicular ad hoc network is discussed. The parameters used to select the cluster head are type of topology handled, infrastructure requirement, road scenario, mobility, messages, direction, vehicle density, velocity etc. Besides that distance between vehicles, direction, final destination, speed and number of hops for message transmission are also used as parameters to elect a cluster head. We propose a Reliable Cluster Forming Protocol in order to provide a reliable path discovery in vehicular adhoc network. Next section explains the VBRCP protocol formation.

III. VEHICULAR BASED RELIABLE CLUSTERING PROTOCOL (VBRCP)

This section describes the working nature of Vehicular Based Reliable Clustering Protocol: VBRCP which performs multicasting instead of unicasting. Multicasting is defined as the method of transmitting the information from a vehicular node to group of nodes at a time in a network [12]. If there are 100 nodes in a network and if a node wishes to transmit a message to any other node, then it has to find the destination node by transmitting a message through all the neighboring nodes. It causes delay and control overhead because, it is not possible to transfer the packet to group of nodes at the same time. This problem is solved by grouping nodes into clusters, which reduces delay and tends to achieve reliability. For example, 10 vehicular nodes are used here to depict the working nature of VBRCP in which 4 clusters are formed with respect to the node connectivity, speed and transmission range. The same working principle would be applied when the number of nodes in a network increases. The same concept has been applied to 20 nodes to trace the output to evaluate the performance.

A. Identifying Neighboring Nodes

Figure 1 is used to describe the way of locating the neighboring nodes. Circles represent the transmission range of nodes which are used to identify the neighboring nodes. Vehicular nodes are free to move at any time due to their dynamic nature and hence Figure 1 is an example temporary network, which is formed by considering the nodes in a random manner [13]. Little circles are utilized inside a large circle or on the circle to signify the individual nodes.
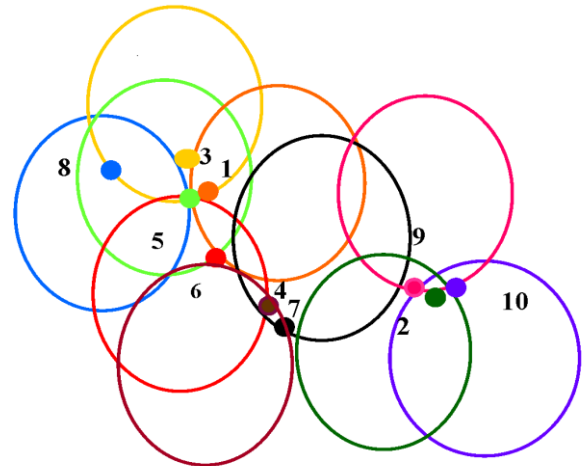

Figure 1. VBRCP - Transmission Range

Here, Node 1 is marked in orange color small circle and its transmission range is marked in the same color large circle. Nodes which go into the transmission scope of node 1 are dealt with as the neighbors of node 1. In Figure1, nodes 3, 5 and 6 are located on the orange circle for our assumption and hence they are treated as the neighbors of node 1 (recorded in second row of Table 1). In the same way, node 2 and its transmission range are marked in dark green in color. Node 9 is placed inside circle 2 and node 10 is situated on the border of dark green circle. Therefore nodes 9 and 10 are considered as the neighbors of node 2 (recorded in third row of Table 1). Similarly other nodes and their transmission range are marked in different colors which are entered in Table 1.

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Table 1   VBRCP-Cluster Head Election

Node	Node Color	Nbd	D	DID	SOD	Bp	Nm	Cw
1	Orange	3,5,6	3	0	10	1	0	3.1
2	Green-Dark	9,10	2	1	4	2	1	2.0
3	Yellow	1,5,8	3	0	9	1	2	3.1
4	Brown	6,7	2	1	4	2	2	2.1
5	Green-Light	1,3,6,8	4	1	11	0	1	3.9
6	Red	1,4,5	3	0	9	1	3	3.1
7	Black	4	1	2	2	3	1	2.0
8	Blue	3,5	2	1	7	2	2	3.0
9	Pink	2,10	2	1	4	2	0	1.9
10	Violet	2,9	2	1	4	2	1	2.0

Acronym:

nbd	neighborhood nodes
D	Degree
DID	Degree In Difference
SOD	Sum Of Difference
Bp	Battery power
Nm	Node movement
Cw	Combined weight

nbd describes the neighbors of each node. nbd of a node is obtained from Figure 1 in such a way that the nodes that enter into the transmission range of a particular node. Degree D represents the number of neighbors of a node. For example, degree of node 9 (marked in pink color) is 2 since it has 2 neighbors (node 2 and 10). DID represents Degree In Difference which is calculated using the degree of neighbors and the number of members (N) to be located inside a cluster. Here, battery power plays a prominent role in electing the cluster head. The increase in the number of members in a cluster will reduce the battery power considerably. In order to overcome the frequent battery drainage, the members of cluster (N) is fixed as 3. Hence DID is given by |D-N|.

For example, DID of node 6 is 0 (3-3) since there are 3 neighbors for node 6 which are represented in Table 1. DID of all other nodes is calculated in the same manner. SOD of a node is calculated by adding the degrees of the neighbors. SOD of node 6 = Degree of node 1+ Degree of node 4+ Degree of node 5 = 3+2+4 =9. SOD of remaining nodes is derived as stated above. Bp is allotted based on the degree of a node. If the degree of a node is 4 then its battery power Bp is 0. The allotted battery power is 1 when the degree is 3. In the same way, Bp is considered as 2 for the degree 2. For node 6, Bp is 1 since the degree is 3. Nm describes the speed of a mobile node. Nm is denoted as 0 when there is no movement and it is represented as 1 when there is a slow movement and also it is given as 2 when there is a fast movement. Combined weight Cw is calculated by,

$$Cw = DID * w1 + SOD * w2 + Bp * w3 + Nm * w4.$$

In order to elect the cluster head, we consider DID, SOD, Bp and Nm as the weighing factors. We select the weights arbitrarily as w1=0.5, w2= 0.3, w3= 0.1 and w4= 0.1 such that w1+w2+w3+w4 =1.

Cluster Formation

10 nodes of Figure 1 are grouped into 4 clusters. Cluster is formed by grouping the neighboring nodes and Cw is used to elect the cluster head. Cluster 1 contains nodes 1, 3, 6 and cluster 2 contains nodes 5 and 8. Nodes 1, 3, 6 and 5 are neighbors to each other. Here node 5 is common to nodes 1, 3, 6 and 8. Hence, we group nodes 5 and 8 together to form a cluster. It is important to note that the nodes of this VANET are dynamic in nature and any vehicular node can move away from one cluster and may join in any other cluster at any time. So cluster formation is done accordingly.

Cluster Head is elected by choosing the node with minimum combined weight Cw among the members of a cluster. If two members have the same Cw, then CH is elected randomly. First Cluster contains nodes 1,3 and 6 in which their computed Cw is 3.1 for all the three nodes and hence node 1 is chosen as the cluster head randomly. Node 5 whose Cw is 3.9 and node 8 whose Cw is 3.0 are made to form the second cluster. Node 8 becomes the cluster head since it has the minimum combined weight. Third cluster is formed by grouping nodes 2,9 and 10. Combined weight of these nodes is 2.0, 1.9 and 2.0. Hence node 9 is elected as the cluster head for the third cluster. Last cluster contains nodes 4 and 7 in which node 7 (Cw=2.0) is made to act as a cluster head since it has the minimum Combined weight. Connectivity is achieved between the clusters by determining the neighbors of each other. For example, connectivity among cluster heads 1, 8 and 7 is achieved as they are neighbors to each other.

Routing

Routing in VANET [12] is defined as finding the reliable path to disseminate the information from the source node to the destination node via various cluster heads. VBRCP performs multicasting where a CH can send the information to its neighboring CHs at a time, only if the connectivity between them exists. Members of a cluster can receive the information only from the CHs. Routing in VBRCP [12] is done in two stages namely Route Discovery and Route Maintenance. Each node sends its ID, CH_ID, Cw to its group members during Route Discovery which will enable us to elect the Cluster Head. ID denotes the unique number of each vehicular node where as CH_ID is updated after identifying the Cluster Head. Therefore, initially it is said to 0 and the calculated Cw is taken from the table. After successful broadcasting, every node in a network knows its own Cw and the neighbor nodes Cw. If a node finds that it has the minimum Cw after receiving the information from its neighbors in group, then it identifies itself that it becomes the Cluster Head and updates its ID in CH_ID field. The same is broadcasted to all the nodes in a group and hence the other group members are made to forward the information through the desired Cluster Head. Routing table is maintained and is updated every time the node moves or the link between the nodes expires. Route Maintenance is done when there is a link breakage or node failure. For example, node 3 wishes to send a packet to node 5 and is done through CH1 and CH8. Reliable path is calculated for the given cluster and is explained in the illustration section.

IV. UNIVERSAL GENERATING FUNCTION TECHNIQUE

In recent years, Universal Generating Function Technique (UGFT) is used as an important technique to analyze the reliability of a network. It is straightforward, effective, and universal and has an enterprise approach in calculating the network reliability. It is fast enough to be used in these problems. The UGFT is based on definition of a u- function of discrete random variables and composition operators over u-functions. The u-function of a variable X is defined as a

$$u(z) = \sum_{k=1}^{K} P_k z^{X_k}$$

polynomial where the variable X has k possible values and P_k is the probability that X is equal to X_k. The UGFT is well suited for MANET and VANET reliability evaluation due to their stochastic behavior [11,12]. One can use the same procedures for systems with a different physical nature of element's performance measures and different natures of interaction between system elements.

Definitions and Algorithm

Each transmission has its own probability. Hence, each transmission requires a unique representation. The probability of transmission of messages from any node to its CH and reaching the destination D is denoted by $P_{i:CH_i, CH_j:D} X^D$. If the message starts from a node and passes through any path and reaches the destination successfully then the corresponding Tp are multiplied. That is,

$$P_{i:CH_i, CH_j:D} X^D = P_{i:CH_i} X^{CH_i} * P_{CH_i:CH_j} X^{CH_j} * P_{CH_j:D} X^D$$

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Definition 1

The node UGF (for member node) is defined as a polynomial in X such that $u(i) = P_{i:CH} X^{CH}$ where $P_{i:CH}$ represents the probability of passing the packets from node i to the CH. Here CH is the head of the cluster from where the node i is located.

Definition 2

The node UGF for a CH is defined as a polynomial in x such that

$$u(CH_i) = \sum_{k=1}^{M} P_{CH_i:CH_j:D} X^D$$

where k denotes the number of possibilities and M denotes the total number of possibilities through which the data can reach D from CHi.

Definition 3

The link UGF is defined as the composition of node UGF and CH UGF and is given by

$$LR_{i:D} = \left\{ \sum_{K=1}^{M} P_{i:D} \right\} X^D = u(i) * u(CH_i)$$

where $P_{i:D}$ denotes the probability that the information is passed from node i to destination D with M number of possibilities via various CHs'. This is achieved by combining the UGF of node i and its CH which is denoted as $u(i) * u(CH_i)$.

Illustration

VBRCP is applied in the VANET that consists of 10 nodes in which the transmission range is formed among the nodes during phase I and Cluster Head(CH) is elected during phase II by using D, DID, SOD, Bp, Nm & Cw. Nodes in this VANET are grouped into 4 clusters so that reliability and efficiency are achieved. Figure 2 represents cluster formation in which a node inside a small circle denotes the CH and nodes located inside a large circle denotes the member nodes. This section describes the reliability calculation by illustrating different examples using Table 2 and Table 3.

Table 2   Transmission Probabilities between CHs

Between CHs	Probability
1-7	0.8
1-8	0.8
1-9	0.7
7-8	0.9
7-9	0.6

In order to validate the algorithm numerically we have chosen the probability values arbitrarily for passing information between CHs and within CHs and are listed in Table 2 and Table 3. These values are used to calculate the link reliability.

Table 3. Transmission Probabilities within Clusters

Cluster no	Within clusters	Probability
1	1-3,1-6	0.6,0.5
2	5-8	0.5
3	4-7	0.8
4	9-2,9-10	0.9,0.6

Table 3 describes TPs for disseminating the information within a cluster where the transmission is carried out between the CH and its member nodes.

Example 1:

A data has to be sent from node 2 to node 5. The corresponding cluster heads are CH 9 and 8. Data transmission is done by including the following possibilities.

Reliability is calculated as

$$LR_{2:5} = u(3) * u(CH_9) = \sum_{k=1}^{4} P_{2:5} X^5$$

$$= P_{2:9,7,8:5} + P_{2:9,1,8:5} + P_{2:9,1,7,8:5} + P_{2:9,7,1,8:5}$$
$$= [0.9*0.6*0.9*0.5] + [0.9*0.7*0.8*0.5] +$$
$$[0.9*0.7*0.8*0.9*0.5] + [0.9*0.6*0.8*0.8*0.5]$$
$$= 0.243 + 0.252 + 0.2268 + 0.1728 = 0.8946 \approx 0.9$$

V. CONCLUSION

As per the dynamic nature of vehicular nodes in VANET, it is made clear that, the routing protocols designed must always be efficient, scalable and reliable. Reliability will not be achieved easily while transmitting the safety information among ongoing vehicles on the road. Many authors have proposed clustering based algorithms for VANET.

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Here, we have proposed VBRCP, to achieve reliability, scalability and efficiency by applying TPs between CHs and within clusters. Reliability of VBRCP is defined as the probability that the message is transmitted from source node to destination node through CHs successfully without any delay and packet loss. This work devotes to assess the VANET reliability using UGFT. Link reliability is calculated by using node UGF $u(n)$ and Cluster Head UGF $u(CH_i)$. Performance of VBRCP is compared with other existing protocols. Simulation is done by using NS-2(Network Simulator) which proves that, VBRCP performs well compared to all the other existing protocols in terms of packet delivery, delay, bandwidth consumption, packet loss and throughput.

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