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PROFICIENT ALGORITHM FOR SUPERIOR WARNING MESSAGE BROADCAST IN VANET

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ABSTRACT

In the past few decades, the number of vehicles on road has been rapidly increasing. Due to this high density of vehicles, road accidents and the potential threats on road are also increasing. To reduce these factors, VANET technology which uses moving car as nodes in a network to create a mobile network is adapted to enhance the vehicular technology by disseminating messages to each other. Since vehicles have high mobility, warning messages have to be quickly disseminated in order to reach maximum number of vehicles on road. The notification to the nearby vehicle is simply done by broadcasting the messages, which is retransmitted over and again by the vehicles simultaneously to other nearby vehicles. Selection of a set of forwarding nodes is a challenging task. In this work, a Cell Structured Broadcast Modeling Algorithm (CSBMA) is proposed to design a virtual hexagon network to remove the broadcast storm problem in real urban scenarios. The proposed work is a sender-initiated broadcast approach in which a sender estimates its neighbor location with a non-geometric broadcast approach and selects a set of forwarding candidate nodes located at the boundary of sender's nodes based on communication area overlap values. A simple random backoff mechanism is also proposed to reduce the packet collisions.

Keywords: *Mobility Models, Broadcast Storm Problem, Warning Message Dissemination, VANET, Non-Geometric Approach, Virtual Hexagon-Based Coverage, Boundary Node Estimation.*

1. INTRODUCTION

Vehicular Ad-hoc Networks (VANETs) are wireless networks recognized as an important element of the future Intelligent Transportation System (ITS) to mitigate serious problems like traffic jams and accidents [8] without a predefined infrastructure or centralized administration. VANETs are attractive for situations where communication is required but deploying a fixed infrastructure is impossible. VANET has become a popular field of research in industry and academia for the past few years. This is due to the demand for the next-generation ITS to provide real-time traffic management and commercial services such as freeway management, road accident avoidance and safety, driver assistance, route planning and passengers comfort on the road [2]. Real-time position information is required for many vehicular applications such as ITSs, navigation, and location-based services (LBSs), Global Positioning System (GPS) is the most important positioning tool that can be considered for these applications. Vehicles are equipped with wireless communications devices that enable communication between vehicles and fixed roadside unit (RSU) or between vehicle and vehicle [4]. Since vehicles rapidly change their positions, they result in a highly dynamic topology. The wireless links may be broken and re-established on the-fly. Mobility models characterizing the vehicular motiondepend on the traffic density, road layout, driving behavior etc. [6]. Mobility models also describe the movement pattern of mobile users including their speed, positions and accelerations over time.

Vehicles make connection with other vehicles on a short communication range. This connection exists only for few minutes since vehicles move on its own direction and the two vehicles may never meet again. These connections may be lost and new connection may be re-establish with other vehicles in a short period of time as vehicles have high mobility. One of the most important issues in the protocol design of VANET is data dissemination. When a vehicle detects a hazardous situation such as slippery road, accident etc. it should notify this situation to its nearby vehicles that could face this problem in a short period of time. A simple way to inform other vehicles is broadcasting the warning message. This alert message is retransmitted over and again by the vehicles simultaneously to the other nearby vehicles to warn about the abnormal situation over the road. This retransmission of warning messages may also lead to problem namely Broadcast Storm Problem. Many of the existing adaptive techniques for VANET usually consider vehicle features such as their speed, density and location in the scenario. Most of the works related to VANET in the literature mainly focus on end-to-end routing in highway scenarios. Several approaches have also been proposed for VANET to improve the warning message dissemination but none of them has been tested in real urban scenarios [9]. Adapting to the environment where the vehicle is moving is essential to improve the effectiveness of the warning message dissemination and thereby reducing the broadcast storm problem.

Profile-driven Adaptive Warning Dissemination System (PAWDS) [9] developed to improve the warning message dissemination in urban scenarios, consider the dynamic roadmap profiling to reduce the broadcast storm problem. In [9], they have reduced the broadcast storm problem, by transmitting the messages based on the roadmap and the density of vehicles on the road. Instead of forwarding the warning message by all vehicles in the network some nodes are selected for rebroadcasting the warning message. Nodes are selected at certain distance from the sender node based on the GPS information. GPS may not provide the accurate location information and has 50 to 100m of error bounds [14]. Selection of a set of forwarding nodes efficiently for broadcasting is a challenging task to improve the warning message dissemination. Important messages are usually broadcasted among vehicles to inform each other about their local parameters such as speed and location. A safety message, generated by a specific vehicle which detects or experiences a hazard or an unusual event is broadcasted to notify its neighbors, as far as possible [13], [1].

Vehicles detecting abnormal situations on the road should notify this situation to its nearby vehicles. Since a blind broadcasting of warning message increases the number of messages in the network which leads to redundant messages in the network and packet collisions. Simultaneous forwarding without any condition called broadcast storm problem must be avoided or reduced [18]. The proposed work is a Cell Structured Broadcast Modeling Algorithm (CSBMA) to improve the warning message dissemination in real urban scenarios and select the appropriate forwarding nodes efficiently for completely removing the broadcast storm problem. A virtual hexagonal network is constructed to minimize the communication area overlaps of the vehicles and maximize the broadcast coverage area. The nodes are selected for rebroadcasting the warning message only at the boundary of the sender's communication range without using GPS.

The rest of the paper is organized as follows. Section 2 presents several broadcast storm reduction techniques and adaptive forwarding mechanisms related to the work. Section 3 justifies the necessity of city profile information and their classification. Section 4 presents the proposed scheme. Section 5 describes the implementation of CSBMA. In Section 6, the results using the proposed scheme are presented and analyzed. Finally, Section 7 concludes the paper.

2 BACKGROUND AND RELATED WORK

In the networking literature, there are several works that proposed either broadcast storm reduction techniques or adaptive mechanisms to enhance message dissemination. The following section deals with the most representative work related to the proposed work.

2.1 Broadcast Storm Reduction Techniques

The Counter-based scheme [18] uses a counter c to keep track of the number of times the broadcast message is received and a threshold C is set. Whenever $c \geq C$, it inhibits further rebroadcast. The Distance-based scheme [18] uses the relative distance between vehicles to check whether to rebroadcast or not. When the distance d between two vehicles is short and the Additional Coverage (AC) of the node is lower, rebroadcasting the warning message is inhibited. If d is larger, AC will also be larger. The Location-based scheme [18] based on more accurate locations for the broadcasting vehicles, needs an accurate geometrical estimation (with convex polygons) using GPS. The main drawback of this scheme is the high computational cost for calculating the AC.

Other rebroadcast schemes [19]proposed for VANET are slotted 1-persistence, the slotted p-persistence and weighted p-persistence. These three probabilistic and timer-based broadcast suppression techniques are not designed to solve the broadcast storm problem, but they can reduce the severity of the broadcast storm by allowing only nodes with higher priority to access the channel as fast as possible. These schemes are specifically designed for use in highway scenarios. The Last One Scheme [17] reduces the broadcast storm problem. Choosing the most distant vehicle from the warning message sender will be the next node for the rebroadcast. This scheme uses GPS information from the sender vehicle and the possible receivers to calculate the distance. GPS information must be accurate to achieve good results, and it is not correctly specified how a node knows the position of its nearby vehicles at any given time. This scheme is useful only in highway scenarios but it does not consider the impact of obstacles. In Stochastic broadcast scheme [16] rebroadcast nodes are selected according to a retransmission probability. This scheme does not consider urban scenarios and it is tested only for an obstacle free environment.

Enhanced Street Broadcast Reduction (eSBR) scheme [11] uses two types of messages for communication namely, warning message, informing about an emergency situation and beacon message informing about the position, speed etc. of the vehicle. The message is rebroadcasted after a fixed time interval if the distance between the sender and receiver is greater than the initialized rebroadcast distance. The message ID is saved up on receiving each message. If the same message is received again, by comparing it with the already existent ID, the message is discarded and is not forwarded again by the vehicle. The Cross Layer Broadcast Protocol (CLBP) [3] uses geographical locations and velocities of vehicles to select the forwarding vehicles efficiently. This scheme uses BRTS and BCTS frames exchanging for reliable transmissions. However this scheme focuses on single-direction environment like highway scenarios and its performance has not been tested in urban scenarios.

2.2 Adaptive Forwarding Mechanism

Efficient dissemination of messages still faces many challenges in the current research scenario of VANET. Backfire Algorithm [10] an adaptive forwarding mechanism which controls the amount of redundant messages thereby improving message dissemination. In this Vehicles calculate the density of neighbor vehicles to decide whether to forward or not. The auto adaptive dissemination scheme - Adaptive Copy and Spread (ACS) [7] Algorithm - for VANETs, dynamically adjusts the dissemination strategies based on the moving patterns of vehicles such as direction and velocity. The ACS scheme automatically increases or decreases the number of message replicas inside the broadcast area, and vehicles can decide when to start or stop broadcasting a message. Adaptive spread and copy is designed to keep the message at the effective area's boundary for informing this situation as soon as possible when the vehicle enters. Profile-driven Adaptive Warning Message Dissemination System (PAWDS) [9] is proposed to improve the warning message dissemination by considering the city profile. Messages are transmitted based on the vehicle density and roadmap scenario for reducing the broadcast storm problem. Selection of rebroadcast node is based on the GPS information but GPS equipment may not provide accurate information all the time [17]. A Geometry-based approach [15], where each node is equipped with a GPS and a set of forwarding nodes are optimally selected in the network.

In summary, most of the adaptive techniques specified above in the literature focus to reduce the broadcast storm problem and improve the message dissemination in highway scenarios or consider the message propagation in only one direction. Some message dissemination schemes only consider message features such as speed, location, density and not take into account the roadmap profile. Hence, there exists the need for the warning message dissemination without broadcast storm problem in urban scenarios. In this work a Cell Structured Broadcast Modeling algorithm (CSBMA) is proposed to design a Virtual Hexagonal network in which either three or six nodes located at the boundary of the sender’s communication range are selected for rebroadcast. The proposed work uses a non-geometric broadcast approach for selecting a set of forwarding nodes efficiently, thereby reducing the redundant messages and packet collisions. Selection of rebroadcasting node is based on the communication area overlap value of the vehicles in the current scenario. Without GPS, vehicles calculate the distance of neighbor nodes based on the received signal strength. Due to the signal strength fluctuations and noise, estimating the distance between sender and receiver is difficult.

3. CITY PROFILE CLASSIFICATION

Roadmap serves as a scenario for improving the efficiency of warning message dissemination. One of the most important issues in the protocol design of VANET is absence of existing mobility model [12] for imitating the realistic behavior of vehicular traffic. Road topology considered as one of the parameter for supporting mobility model has a vital influence to enhance the message dissemination in VANET. The efficiency of alert dissemination is improved when city profile information is taken into account [9]. Existing cities are classified by their street profiles into: Simple: maps with low density of streets and junctions; Regular: maps with medium density of streets and junctions; Complex: maps with high density of streets and junctions. When the vehicle determine the city profile and density of vehicle where the vehicle is moving, the appropriate message dissemination scheme is chosen. The three message dissemination schemes are

Full dissemination: When the vehicles move in a low density area then vehicles can send as many messages as possible since the vehicles in the city are less.

Standard dissemination: Vehicle should maintain balance between number of messages sent and number of messages received.

Reduced dissemination: Vehicles send as few messages as possible because the vehicles move in a high density area.

4. THE PROPOSED SCHEME

In multi-hop broadcastings, selection of a set of forwarding node is a challenge. A non-geometry-based broadcast approach is proposed and a simple random backoff mechanism is also proposed to avoid packet collisions. In order to increase the network broadcast coverage area but to minimize communication area overlap and avoid packet collisions a virtual hexagon-based coverage is popularly deployed and the forwarding nodes located at the boundary of the sender's communication range are selected. Design of virtual-hexagon structure is constructed using equation (1).

The node transmitting information is node A as shown in figure 1, whereas the nodes B, C and D are all receiver nodes respectively. Nodes B, C and D are located at the communication boundary of Node A i.e. at a distance of R. The angle to the node overlap area is represented as Θ. Thus nodes B, C and D have communication area overlap with node A respectively. The nodes B, C and D have to be located at a distance from each other such that they have minimum overlap area with each other. The nodes that appear at the boundary of sender node are predicted using the communication area overlap values.

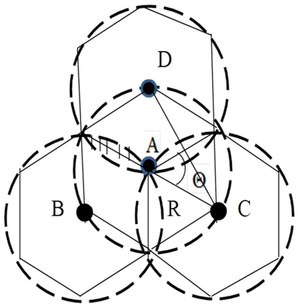

Figure 1: Virtual Hexagon Network

For two nodes having a communication area radius R each, the angle to the node overlap area is represented as Θ and at a distance d, the overlap area [5] is given by the formula

$$A_{overlap} = 2\left(\pi R^2 \times \frac{\theta}{2\pi} - \frac{d}{2}\sqrt{R^2 - \frac{d^2}{4}}\right) (1)$$

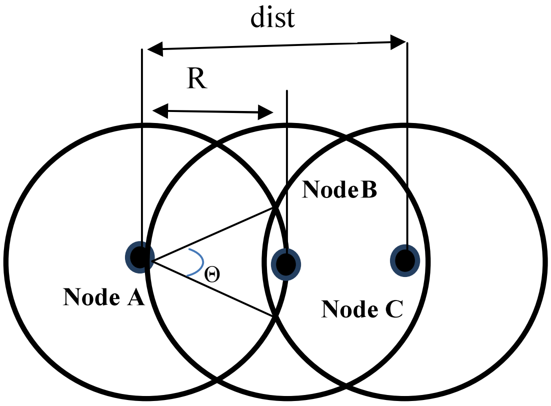

Figure 2: Overlap Area Calculation

Let nodes A and B be located with a distance R apart as shown in figure 2. Here, the dist. and Θ become R and 2π/3, respectively. That is the node is located at the boundary of the sender node. Then, the overlapped area can be calculated based on the equation (1) is

$$A_{overlap} = 2\left(\pi R^2 \times \frac{1}{3} - \frac{R^2}{2}\sqrt{\frac{3R^2}{4}}\right) \quad (2)$$

$$A_{overlap} = 2R^2\left(\frac{\pi}{3} - \frac{\sqrt{3}}{4}\right) \quad (3)$$

Area of a circle is $A = \pi R^2$ (4)

Now comparing overlap area with respect to the communication area of a single node.

$$Ratio = \frac{A_{overlap}}{A} = \frac{2R^2\left(\frac{\pi}{3} - \frac{\sqrt{3}}{4}\right)}{\pi R^2} \quad (5)$$

$$Ratio = \left(\frac{2}{3} - \frac{\sqrt{3}}{2\pi}\right) \approx 0.391 \quad (6)$$

Thus a node satisfying the communication area overlap ≈ 39.10 % is selected as the rebroadcasting node. Node C has minimum communication area with node A. While calculating for minimum overlap area, the average nodal distance between the rebroadcast node is found out to be $\sqrt{3}R$ and $\Theta = \pi/3$.Using overlap equation (1).

$$A_{overlap} = 2\left(\pi R^2 \times \frac{\pi}{3\times 2\pi} - \frac{\sqrt{3}R}{2}\sqrt{R^2 - \frac{\left(\sqrt{3}R\right)^2}{4}}\right) \quad (7)$$

$$A_{overlap} = 2\left(\pi R^2 \times \frac{1}{6} - \frac{\sqrt{3}R}{2}\sqrt{\frac{R^2}{4}}\right) \quad (8)$$

$$A_{overlap} = 2R^2\left(\frac{\pi}{6} - \frac{\sqrt{3}}{4}\right) \quad (9)$$

$$A_{overlap} = R^2\left(\frac{\pi}{3} - \frac{\sqrt{3}}{2}\right) \quad (10)$$

Now comparing overlap area with respect to the communication area of a single node.

$$Ratio = \frac{A_{overlap}}{A} \quad (11)$$

$$Ratio = \left(\frac{1}{3} - \frac{\sqrt{3}}{2\pi}\right) \approx 0.0577 \quad (12)$$

Hence the calculated overlap area with approximately 5.8% of the communication area of a single node is selected as the rebroadcasting node. Since the nodes are dynamic in nature, a virtual hexagonal network has to be designed in which the rebroadcast nodes are selected based on two conditions:

1. The rebroadcasting nodes are situated over the communication boundary of the sender node.
2. The node selected for rebroadcast is distant enough from the nearest rebroadcast node such that there is minimum overlap in the communication area of both the broadcast nodes.

5. ALGORITHM IMPLEMENTATION

Each vehicle is equipped with GPS and city profile is identified by using onboard GPS system. There are two types of messages namely, warning messages and beacon messages. Warning messages are used to inform other vehicles about the abnormal conditions on the road and beacon messages are exchanged among the vehicles to inform about their speed, position etc. Vehicle density is calculated by exchanging the beacon signal among the nearby vehicles. The most important parameter of the algorithm is city profile information and the density of vehicles on the road. The algorithm efficiently selects the most suitable message dissemination scheme based on the profile of the street map and the estimated vehicle density. Table 1 shows the parameters used in each working mode in the algorithm. Pseudo-code of CSBMA is shown below and T represents the time taken to reconfigure the system.

Algorithm 1: CSBMA () pseudo-code

```
Use standard dissemination scheme
While (1) do
obtain street map using GPS
estimate the vehicle density using beacon message
if (city-profile is simple) then
        if(vehicle density>25/$km^2$) then
        use reduced dissemination scheme
        non-geometric broadcast scheme
        else
        use standard dissemination mode
        non-geometric broadcast scheme
else-if(city-profile is regular) then
        if(vehicle density>50/$km^2$) then
        use standard dissemination scheme
        non-geometric broadcast scheme
        else
        use full dissemination scheme
        non-geometric broadcast scheme
else-if(city-profile is complex) then
```

```
        if(vehicle density>$75/km^2$) then
        use standard dissemination scheme
        non-geometric broadcast scheme
        else
        use full dissemination scheme
        non-geometric broadcast scheme
sleep(T);
```

Working mode	Interval between consecutive messages	Broadcast scheme	Min. rebroadcast distance
Full dissemination	2 seconds	Counter based	--
Standard dissemination	4 seconds	eSBR	200m
Reduced dissemination	5 seconds	Distance based	250m

Table 1: Working Modes and Key Parameters

6. SIMULATION AND PERFORMANCE EVALUATION

Since deploying and testing of VANET protocol is economically not feasible in the real world without testing the protocol, simulation plays a vital role in imitating the realistic behavior of vehicular traffic. Matlab is good for implementing the algorithm accurately and provides mathematical proof for the algorithm implementation. Matlab offers many predefined mathematical functions for technical computing which contains a large set of mathematical functions. Simulation results presented in this paper are done using Matlab 2010a. This work is simulated with 200 vehicles in the roadmap scenario and result shown in the Figure 3.

In Figure 3, all the black coloured blank circles represent vehicles i.e. nodes at an instant of time. The big red coloured dot represents the initial sender node which has encountered a problem which may be like accident or severe traffic jam. Now this node calculates apart from broadcasting, also identifies the nearest nodes that can rebroadcast the message using virtual hexagonal network. The green dots represent the rebroadcast nodes identified which satisfies the virtual hexagonal network conditions. In the next step, these green nodes tends to act like the sender node and again identifies the rebroadcasting nodes. The yellow coloured nodes represent the forwarding nodes identified by the green coloured nodes. The red triangle dots represent the rebroadcast nodes identified which satisfies the virtual hexagonal network conditions. The yellow coloured node acst as the sender now and selects the red triangle nodes as the next rebroadcasting nodes. The blue triangle dots represent the rebroadcast nodes identified which satisfies the virtual hexagonal network conditions. In the next step, these blue triangle nodes tend to act like the sender node and again identifies the rebroadcasting nodes. The blue colored triangle now acts as the rebroadcasting node selected by the red triangle node. The red coloured star nodes represent the next forwarding nodes identified by the blue coloured triangle nodes. The blue coloured star nodes now select as the next rebroadcasting node by the red coloured star sender node. This process is repeated over and again so as to transmit the information to all the vehicles in VANET. The nodes to become the rebroadcast nodes can receive request from two or three nodes simultaneously due to which there is a probability of multiple re-broadcast by the same node. This is avoided by enabling only the first received request of rebroadcast and discarding all the upcoming requests. Once a node is selected for rebroadcast it is never again acted as the rebroadcasting node of another node. A random backoff mechanism is also proposed to reduce the packet collisions. Simulation results shows that efficiency of the alert dissemination is increased and the broadcast storm problem is reduced by considering virtual hexagon-based coverage.

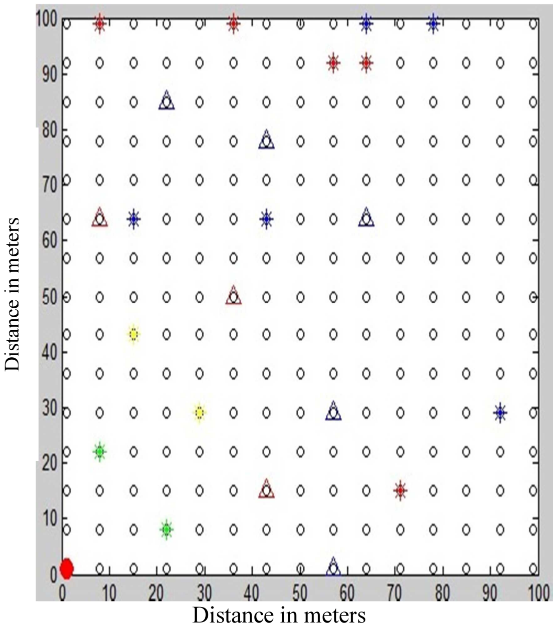

Figure 2: Selection of Rebroadcasting Nodes

Selection of a set of forwarding nodes is a challenge in VANET. Figure 4 represents the number of broadcasting nodes in the scenario. About 38 nodes act as rebroadcasting nodes when simulated with 200 vehicles in the roadmap scenario. This means that on average roughly about 19 % nodes of total population act as forwarding nodes in a particular scenario. Since only 19 % of nodes are used for rebroadcast this avoids the flooding type message dissemination procedure in VANET.

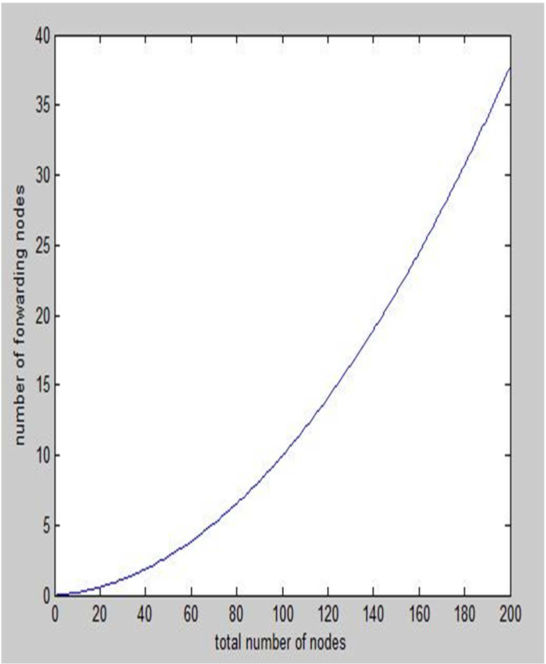

Figure 4: Number of Broadcasting Nodes

7. CONCLUSION

In this work, a non-geometric broadcast scheme and with a simple random backoff mechanism is proposed to improve the message dissemination in VANET. This is a sender-initiated broadcast approach in which sender selects the rebroadcasting nodes that are closely located at the boundary of the sender's communication range based on virtual hexagon-based coverage conditions. CSBMA selects the adequate message dissemination scheme based on the vehicle density and the characteristics of the street where the vehicle is located. Nodes are selected for rebroadcast based on the communication area overlap values. i.e. nodes are selected for rebroadcast only if the communication area overlap is either ≈ 39.10% or ≈ 5.8%. Simulation results shows that only 19 % nodes act as the rebroadcasting nodes when simulated with 200 vehicles in the fragment of the roadmap scenario. None of the node is again and again selected for rebroadcast by another node. Due to this reduction in forwarding nodes, it automatically reduces the broadcast storm problem and enhances the performance of the system and also avoids the flooding type message dissemination procedure. This work shows that adapting to the environment where the vehicle is moving essential to improve the warning message dissemination.

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