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Research paper

Reduction of broadcast storm in urban VANETs using network science

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Abstract

VANETs is very interesting research area. Development of an efficient routing protocol in urban VANETs is a very challenging task that can support communication between vehicles with minimum overhead and maximum reachability. The main overhead in urban network is redundant reception of safety or warning messages. Sometimes we call this broadcast storm. In urban VANETs most of message dissemination protocols use broadcast approach to send messages. Broadcast storm is a major problem in high vehicle density area mainly at cross points. In this paper we reduce broadcast storm or communication overhead by using some techniques developed with help of study of network science. In this paper we study various network parameters of VANETs like node degree distribution, clustering coefficient, average shortest path length, network reachability, mobility pattern, road topology, penetration rate and network overhead. We then show how this information can be used to reduce communication overhead in urban vehicular broadcasting protocol (UVCAST) with no major reduction in performance of existing protocol.

Keywords: *Wireless Networks; Vanets; Rechability; Connectivity.*

1. Introduction

Vehicular ad-hoc networks [1] are a type of mobile ad-hoc networks. In mobile ad-hoc networks nodes can be mobile phone, laptop, camera or any other device that is either able to transmit or receive messages or both. In these networks node may be either fixed or mobile. These devices find each other and make a small network without any infrastructure support known as Mobile ad-hoc network. The vehicular ad-hoc networks are like MANETs but in VANETs nodes are vehicles or moving cars. The main differences between MANETs and VANETs is type of nodes, speed of movement of nodes, mobility pattern and battery power. Vehicles or nodes in VANETs communicate with the help of dedicated short range communication (DSRC) protocol. DSRC is basically IEEE 802.11p [2] amendment of IEEE 802.11a for low overhead operations in VANETs. DSRC IEEE802.11p is generally referred as wireless access in vehicular environment (WAVE). Developing routing protocols for this type of network is very challenging task due to unique properties of VANETs. Communication protocol for such type of network should be able to maximize use of limited bandwidth. Such a protocol should be able to transmit message to all vehicles with minimum overhead and minimum delay. This is very difficult task due to unique properties of VANETs like random and high speed of vehicles, variable vehicle density and dynamic topology of nodes. To construct efficient routing protocol for VANETs we need to first study characteristics of VANETs from network science perspective. A number of studies and research is already done to study unique properties of VANETs mainly addressing mobility of nodes, dynamic topology and bandwidth constraints. In this paper we study VANETs from network science perspective to gain in depth knowledge of network structure.

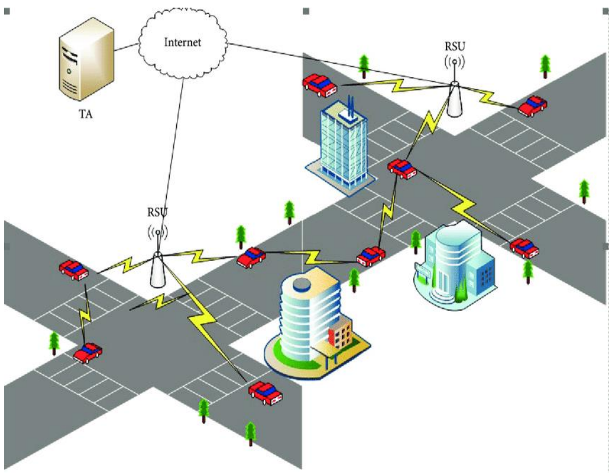

Fig. 1: Architecture of Vanets.

In this paper we ponder VANETs from organize science point of view by utilizing following parameters: hub degree circulation, bunching coefficient, and normal briefest way length, arrange reachibility, portability design, street topology infiltration rate and system overhead. We study these parameters in urban scenario by constructing analytical models and also real life data. Observations derived from study of these parameters helped us to design techniques to improve performance of urban vehicular broadcast protocol (UVCAST). These techniques minimize communication overhead in UVCAST protocol while maintaining the performance of protocol. The paper is organised as follows: Section II contains related work and section III describe real world data used for simulation. In Section IV we analyse various network parameters from network science through analytical models. Section V describes uses of data and models analysed in Section III and apply them to improve performance of UVCAST protocol. Section VI elaborates simulation and results. Section VII describes concluding remarks about work done in this paper and also describes future work possibilities.

2. Related work

Various steering conventions for VANETs have been proposed in writing yet we show just those directing conventions that are important to our work. In [4] creators exhibited RBVT(Road Based utilizing Vehicular Traffic) steering convention which depends on two conventions RBVT-R which is on request directing convention and RBVT-P which is a proactive convention. RBVT-R find course on request and report back to source utilizing course answer which incorporates position of goal and number of convergence focuses.
It picks the way with least number of crossing point focuses without thinking about of vehicle thickness which may cause separation whenever. To conquer this issue a convention named ROMSGP (Receive on Most Stable Group-Path) was displayed in [6]. A steering way is said to be steady if conveyance way comprise of vehicles which are going at same speed (same gathering). The course disclosure is started by sending course ask for (RREQ) parcel to all vehicles and goal hub answer to source with a steady way by course answer bundle (RREP).
A-STAR [7] (Anchor-based Street and Traffic Aware Routing) is a steering convention which works in urban regions by utilizing movement thickness on streets. It utilizes road guide to tally number of cross focuses through which message is conveyed to goal. It likewise utilizes transport course data to know grapple ways with higher network anyway this convention may confront availability issue in a specific day and age. In [8] creators displayed IGRP (Intersection based topographical steering convention) for conveyance of bundles in urban zones. IGRP convention distinguishes convergence focuses through which message is send to target goal. The determination of crossing point focuses for message conveyance depends on specific criteria, for example, network, delay, data transfer capacity use and nature of administration. IGRP functions admirably for settled goal, for example, street side units and isn't much compelling for portable goals. In [9] creators exhibit ETAR(Efficient Traffic Light Aware Routing Protocol for VANETs) which chooses convergence focuses relying on score that is computed in view of following four parameters I) availability ii) movement thickness iii) residual separation amongst source and goal iv) sign of activity light. The message is sent through grouping of chosen convergence focuses step by step. ETAR does not consider genuine conveyance of vehicles which is imperative factor to figure level of network at crossing point focuses. In [10] GPCR (Greedy edge facilitator directing) convention is suggested that is intended for urban situation. This convention utilizes regular organizer charts about streets and crossing point focuses. The convention utilizes two systems: (I) limited covetous sending and (ii) repair methodology. GPCR utilizes a limited ravenous strategy for information sending and furthermore utilizes recuperation method, where the bundles are sent utilizing the turn around covetous mode and can finds a proportionate answer for return back in the avaricious mode. Creators in [12] display GSR (Geographic Source Routing) convention which utilizes geographic guide data to discover most brief separation to goal. The information parcel is conveyed to goal by utilizing crossing point focuses chose at first by source vehicle. The fundamental detriment of GSR directing convention is that it figures full course with contemplating system thickness which is essential factor that may prompt deferred conveyance of parcel to goal.
In [5] an urban VANET broadcasting protocol (UV-CAST) is presented. In our work, we have referred UV-CAST method for message broadcast in urban area because this protocol is lightweight and does not require infrastructure support which eliminates the disadvantages of existing methods discussed above. The details of UV-CAST protocol are given in section V. In our work we will try to improve existing UVCAST protocol by studying characteristics of urban VANETs from network science and by adding some procedures to reduce communication overhead that are not present in the original UV-CAST protocol.

3. Real world data

In our work we use real life data to analyse network properties of VANETs. We use real life data for urban networks to study graph structure of these scenarios. The data set contains different position of nodes and different vehicle density at different time of a day that seems like real traffic pattern. We use data generated by cellular automata model [11] in case of urban VANETs. Cellular automata model assumes blocks of size 125*125. This model consider that two nodes can communication with each other if they are having only one intermediate node in line of sight with in 250 meter distance or can communicate up to 140 m distance in non line of sight. By considering this information, we study snapshots of urban VANETs and analyse graph structure of nodes where nodes are moving cars and there is edge between those nodes that can communicate with each other that are 1-hop away from each other. Next we consider three connectivity regimes and for each scene, we take three connectivity areas low, medium and high connectivity and their equivalent vehicle densities. Now this means varying number of nodes in cellular automata model for urban VANETs it means collecting connectivity information from separate times of the day. The information is given in Table 1.

Table 1: Connectivity vs Density in Urban Areas [11].

4 km^2 urban area		
Density (veh/km^2)	Connectivity (%)	Time of day
12	4	01:00–03:00
65	49	10:00-12:00
85	92	15:00-17:00

4. Network characteristics

Here we will discuss different characteristics of VANETs from network science perspective and analyse them with existing theoretical models on node degree distribution, clustering coefficient, average shortest path length, network rechability, mobility pattern, road topology penetration rate and network overhead. These concepts are defined below:

1) Penetration Rate: It is defined as number of vehicles that can communicate with each other out of total number of vehicles in region. Penetration rate of DSRC protocol is low initially even in high density vehicle area.
2) Node degree: node degree can be defined as total number of edges connected to it. These edges are known as communication path between nodes.
3) Communication Overhead: It can be measured with the help of total number of message transmitted and received in a certain interval of time.
4) Connectivity or Rechability: it is can be stated as number of pair of vehicles which are able to communicate between themselves in a network. If we think of single node connectivity can be defined as number of pair of nodes out of total nodes with which this node can communicate.
5) Mobility Pattern: The mobility pattern of vehicles in VANETs depends upon road structure, traffic lights and time of day.
6) Road Topology: It can be defined as how roads are connected to each other.
7) Clustering coefficient: from network point of view it is defined as probability that if two nodes are connected to a node then these nodes are also connected with each other. In other

words it is equal to number of pair of nodes connected to a particular node are also connected with each other.

8) Average Received Distance: It can be defined distance between point A and B where A is position of vehicle when message was sent to vehicle and position B is location of vehicle where it actually received the message.
9) Average shortest path length: it can be considered as average number of hopes between all possible pairs of nodes in a network. It can be represented mathematically by assuming average shortest path length S that increases proportionally to logarithm of total number of nodes K in a network [9].

$$S=\log (K) \tag{1}$$

A number of small world and scale free networks can be studied from [13]. The equation for average shortest path length is given below.

$$Am (n) = n-z \tag{2}$$

Where n is node degree and z is some constant depending upon particular distribution.

a) Node degree distribution

It can be defined as probability distribution of the number of nodes which are 1-hop away from each node.Figure2 represents node degree distribution for varying densities in area of 4km2 for urban VANETs and their Gaussian fits.

Fig. 2: Node Degree Distributions with Varying Densities and Their Corresponding Gaussian Curves of Urban Vanets [3].

These curves are drawn according to value of table2 by using following formula

$$L (K) =x.e--((k-y)/z)\ 2 \tag{3}$$

Where x, y and z are constants. The above equation is valid only all values greater than zero.

Table 2: Inputs for Node Degree Distribution in Urban Vanets for Best Gaussian Fits [3]

Density (veh/km^2)	X	Y	Z	r-square	sse
12	0.541	-0.18	1.70	0.999	0.0000227
65	0.203	3.82	2.99	0.994	0.000756
85	0.136	5.19	3.56	0.994	0.0005929

b) Average shortest path length

Average shortest path length is drawn as a function of network area by using data from cellular automata model. These fits are parameterized by value given in table3 by using following formula

$$P (Area) = x.Areay + z \tag{4}$$

Table 3: Inputs for Average Shortest Path Lengths of the Best Power Fits in Urban Vanets

Density (veh/km^2)	x	y	Z	R-square	SSE
12	-0.410	-0.31	1.55	0.9753	0.0001096
60	3.381	0.660	1.52	0.9963	0.9074
80	6.505	0.462	-1.0	0.9991	0.208

From figure3, we see that for all the three types of densities the power fitness curve fits well.

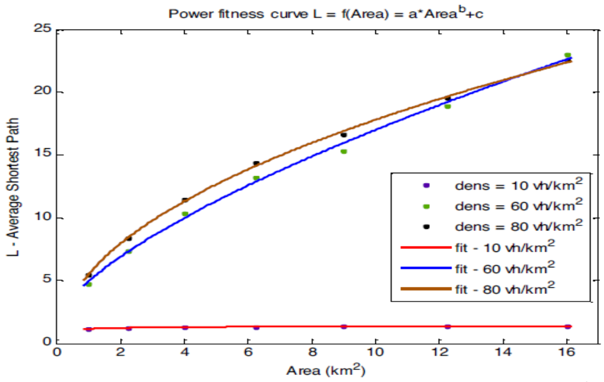

Fig. 3: Average Shortest Path Lengths in Urban Area as Functions of the Network Area and Vehicle Density [3].

c) Clustering coefficient

Clustering coefficient can be defined as probability that if two nodes are r meter away from a common node then these two nodes are also less than r meter away from each other. Figure 4 shows variation of clustering coefficient with respect to different network densities in urban scenario.

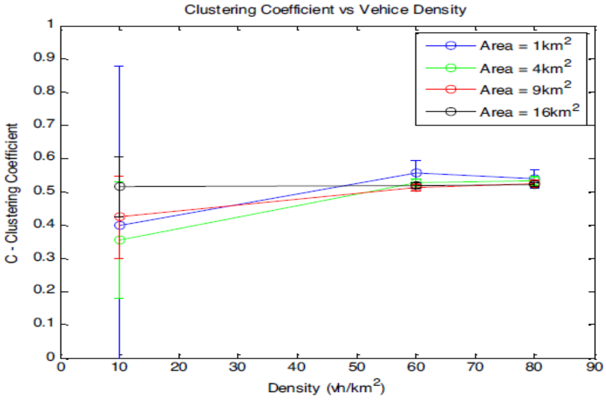

Fig. 4: Clustering Coefficient vs Network Density in Urban Scenario [3].

d) Connectivity

Figure 5 shows connectivity versus vehicle density for urban scenario by using data from cellular automata model.

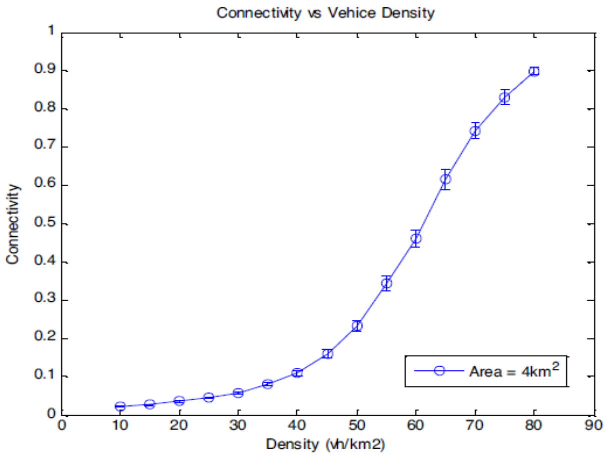

Fig. 5: Connectivity vs Vehicle Density for Urban Scenario [3].

5. Improvement of UVCAST protocol

In [5] UVCAST protocol broadcast safety messages to vehicles in certain ROI (region of interest) in urban. Figure6 shows that vehicle may either operate in high vehicle density regime or low vehicle density regime. In high vehicle density area proposed scheme to reduce broadcast storm depending upon position of vehicle and distance from previous relay. Before rebroadcasting a message node determines average waiting time and transmits message with probability Q. Store and carry forward task is assigned to cars which are not in high density area. Detail working of protocol can be studied from [5]. Figure6 also shows additional Q and R that are used to improve performance of UVCAST protocol. UVCAST protocol gives very good results and ensures delivery of message to nodes in certain region of interest (ROI) with minimum overhead and minimum delay but still there is room for improvement in reachability, average received distance and overhead in terms of number of messages broadcasted and number of message delivered. Note that results shown in figure2 for node degree distribution indicate that a vehicle may have maximum 2 neighbours in case of low density area and each node has more than 3 neighbours in high density area.

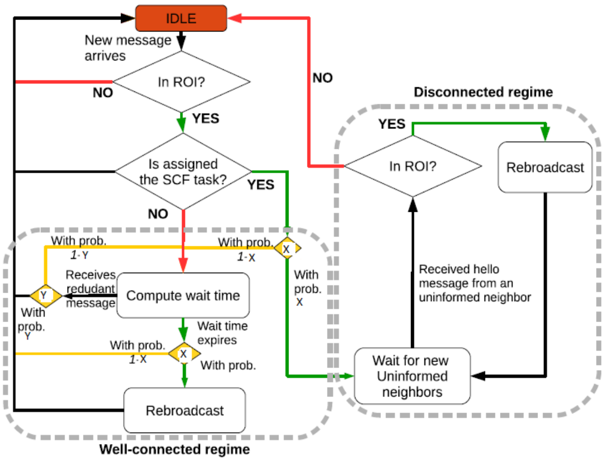

Fig. 6: Flowchart for the UV-CAST Protocol with Additional X and Y Mechanisms [5].

Based upon this indication assume that a vehicle is in low density area if k_{med}<2 and vehicle is in high density area if k_{med}>3. In proposed scheme we introduce two mechanisms Q and R. Mechanism Q is used to suppress the broadcast storm in high vehicle density and R is used to improve network reachability in low density area. Now we propose that to decrease duplicate message in well connected regime reduce the number of store and carry forward nodes in well connected regime. In simple words when wait time expires a node will rebroadcast with probability Q according to below given equation.

Q= {0.5+0.5/kmed-3+1, kmed>3 1, Otherwise} (4)

On the other hand, to increase network rechability in disconnected regime nodes are allowed to rebroadcast again and again before timer expires. This may increase some overhead but as this scheme will work only in low density regime; this will not create a major problem. So a vehicle in disconnected regime should continue to rebroadcast despite of receiving redundant messages with probability 1-R where R can be defined by the following equation.

R= {0.5 + 0.5*kmed/2, kmed<2 1, Otherwise} (5)

6. Simulation and results

We have tested the above proposed scheme in a simulation environment same as described in manhattan grid scenario [5] by considering 1km*1km area as region of interest (ROI) around an accident scene. In starting 10 minute warm up time is given. After that source node broadcasts a message from middle of network and data is collected after 2 minutes of broadcast of message.

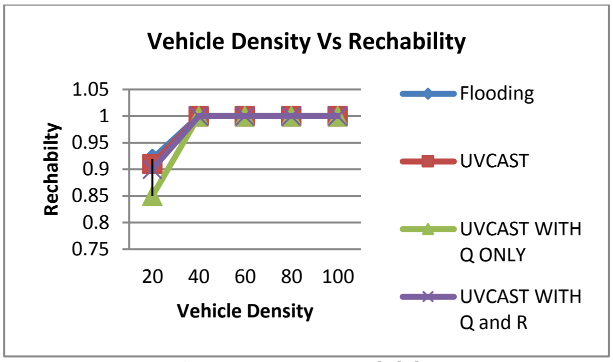

Fig. 6.1: Density vs Rechability.

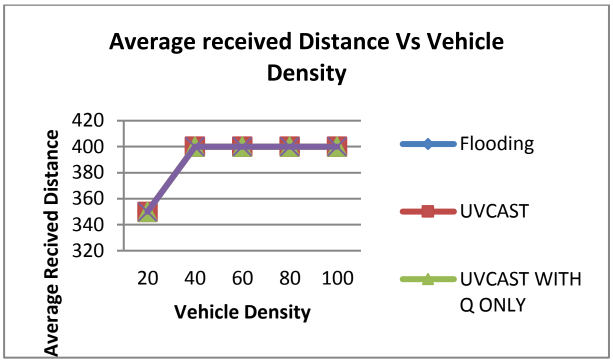

Fig. 6.2: Density vs Average Received Distance.

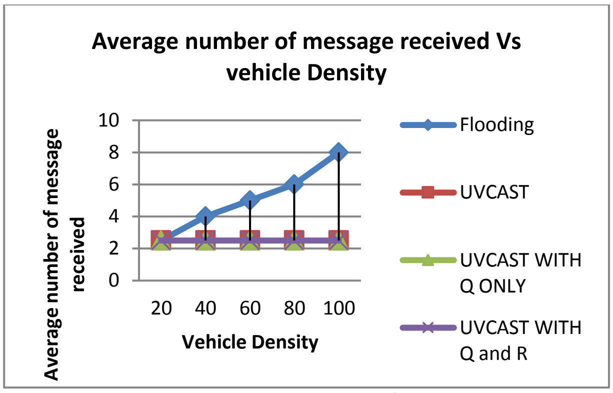

Fig. 6.3: Density vs Average Number of Message Received.

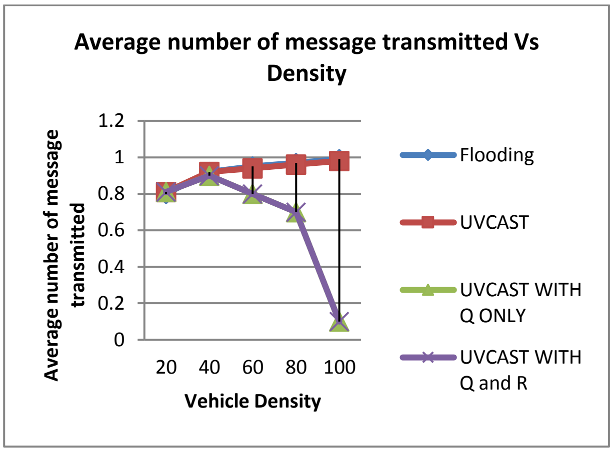

Fig. 6.4: Density vs Average Number of Message Transmitted.

Total 15 simulations were run. Kmed is calculated based on exponential moving average number of neighbours of a node. Simulation results of both Q and R by using four parameters reachability, average received distance and average number of message received per vehicle average number of message transmitted per vehicle are shown in figure7. In figure7 performance of proposed scheme is compared with UVCAST protocol. The bottom two plots show that

Q mechanism significantly reduces the broadcast storm in high density networks. The effect of R mechanism is negligible in well connected regime. For a network with vehicle density 100 vehicles per km2 about 20% improvements in terms of number of average message transmitted per node is estimated when both Q and R techniques are in use. We have also observed that R mechanism helps Q mechanism to reduce number of message transmitted in received per vehicle in high density networks. While proposed schemes are not effective disconnected networks but results in medium and high density networks for improvement of overhead seem quite promising.

7. Conclusion and future scope

In this paper, we have studied highway and urban VANETs from graph structure perspective by taking into consideration a number of network properties like node degree distribution, connectivity, clustering coefficient and average shortest path length. We have designed and evaluated analytical model for these parameters for different network sizes and densities. After that we proposed mechanism to enhance urban vehicular broadcasting protocol. We tested this mechanism by running simulations which gave us good reduction in network overhead without affecting the performance of UVCAST protocol. As for future work we will try to include mobility pattern in proposed scheme.

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