ISSN No. 0976-5697

Volume 3, No. 3, May-June 2012

International Journal of Advanced Research in Computer Science

RESEARCH PAPER

Available Online at www.ijarcs.info

Research and Review of Vehicular Ad hoc Network and Data Dissemination Protocols

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Abstract: Vehicular Ad hoc Network (VANET) is the emerging research area which implements wireless and mobile ad hoc Networks concepts to promote Intelligent Transport System. In VANET, Vehicles are the active nodes to collect the information and to share with other vehicular nodes for safety and commercial applications. The data dissemination is the process of distributing the relevant data to all other interested vehicles using road side units. The challenge of high mobility and frequent disconnection of vehicular nodes leads researchers to focus on data dissemination protocols. The best protocol will disseminate the data about any type of event within the bounded time, limited bandwidth and low latency. Selection of performance metrics may influence the entire research work as either easier or complex one. In this paper, we presented the important metrics that affect the performance of data dissemination by reviewing the existing data dissemination protocols.

Keywords: Vehicular Ad hoc Network, DSRC, Performance metrics, Bloom filter, Cognitive agent.

I. INTRODUCTION

Vehicular Ad hoc NETwork (VANET) is the most popular research topic among wireless-network researchers and has been featured to be useful in providing road safety in addition with commercial applications [1], [2].

In 'Global Status report on road safety' [3], World Health Organization alarms that

a. On the road, over 1.2 million people die each year.
b. 20 to 50 million people suffer nonfatal injuries.
c. Traffic injuries are still increasing in most regions and 90% of deaths on the world's roads occur in low and middle-income countries.
d. More people die in road accidents in India than anywhere else in the world.
e. In India, the average injury rate by accidents is 13 people per hour.

Hence research activities have shown keen interest to Intelligent Transport System (ITS) at various levels.

The main objective of the VANET is to provide safety and traffic management on the road. Figure 1 represents simple VANET scenario where vehicles are acting as the nodes of adhoc network along with Road Side Unit (RSU). A particular vehicle can notify nearby vehicles about abnormal conditions and the notification also be replicated to other networks using RSU. Commercial applications based on Internet, audio streaming, video streaming are also been focused on VANET scenarios. In October 1999, The Federal Communication Commission (FCC) allocated the 5.9 GHz band for DSRC (Dedicated Short Range Communication) based applications including Inter Vehicle Communication (IVC) and Roadside unit-Vehicle Communication (RVC). In 2003, DSRC service with 75 MHz of spectrum in the 5.850 to 5.925 GHz bandwidth was established for ITS [4]. A study [5] has demonstrated that communications among vehicles can exploit the short-range IEEE 802.11 based radio interface technology.

Number of research has been done on VANET communication. Congestion control [1], medium access control (MAC) issues [6], transport safety issues [2], [7], real-time video streaming between vehicles [8] and data dissemination protocols [9], [10], [11] are the broaden research areas of VANET.

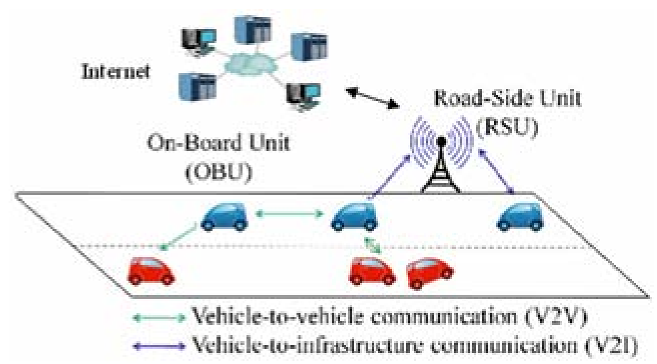

Figure 1 VANET Communication

This paper attempts to compare the performance of existing data dissemination protocols, to find out the factors affecting the performance of data dissemination and to highlight the relevant performance metrics to provide real research platform among VANET surfer.

The remainder of this paper is organized as follows. Section II describes the applications of VANET. In section III, the factors which affect the performance of data dissemination are identified. The relevant metrics for data dissemination protocols are also highlighted in this section. Sections IV and V reviews the set of existing protocols and comparative results. Finally, section VI concludes the review.

II. VANET'S APPLICATION

VANET can be used for number of potential applications with highly dissimilar requirements. These applications are classified into three major classes as,

a) Safety applications.

b) Convenience oriented applications.

c) Commercial oriented applications.

B. Safety Applications:

The safety applications are used for driver assistance and safety warning. It is an interdisciplinary attempt involving many research fields like computer science, automobile engineering, cognitive science, and psychology. The application senses the condition of road, traffic and vehicle always. The emergency messages like vehicle collision, forward obstacle detection, left or right turning and road conditions are informed to driver [12] or RSU for immediate reaction.

Some of the vehicular safety applications [13] are,

a) Emergency Brake Warning**:** Sudden braking of a vehicle will be warned to other vehicles which are in the forward path.

b) Forward collision warning: Warns the forward vehicles about the impending rear-end collision.

c) Blind spot warning or Lane change warning**:** When ever the vehicle node faces blind spots or curve road the warning message of accident prone zone will be delivered. Similarly on the multilane road if any vehicle changes its current lane to some other immediately all other nearby vehicles should be informed

d) Intersection movement assist**:** Whenever the vehicle entered into road intersection region, it will be assisted by this system based on business of the intersection.

e) Do not pass warning**:** Gives warning when oncoming vehicle poses collision threat while changing the lane.

f) Control loss warning**:** Due to any mechanical problem the vehicle may lose the control. That time the self-generated warning will be given to other vehicles.

C. Convenience Oriented Applications:

To save or simplifies the work of vehicle these applications can be added.

a) Driver Assistance**:** Dramatic change of direction, current locality, and information about potential hazards are some of the driver assistance applications [14], which can give more time to react and avoid accidents. Intelligent Driver Assistance System (I-DAS) [12] can address adaptive cruise control, lane departure warning, parking assistance, collision avoidance system, driver drowsiness detection, automotive night vision applications.

b) Weather Information**:** Weather information can be requested or updated via DSRC. Based on the information, the routing path may be taken..

c) Parking Availability Notification (PAN): PAN information helps to find the availability of space in parking lot in a certain geographical area.

d) Mapping service**:** For the convenience vehicle routing, highway and urban area maps may be displayed to avoid the traffic jam and accident.

D. Commercial Oriented Applications:

They will provide entertainment and commercial applications to the passengers through web access, audio streaming and video streaming. The most important commercial oriented applications are

a) Automatic toll fee collection**:** When vehicle entering into highway toll booths, without stopping the vehicle the toll fee can be collected automatically from the bank account and intimated to the vehicle's owner.

b) Automatic Dialing**:** Using an existing cellular infrastructure, automatic call service can be provided when the passenger in the vehicle want to make a call.

c) E-access**:** These applications provide internet access, communication between passengers in different vehicle nodes and also permit them to play games.

III. VANET'S PERFORMANCE FACTORS AND PARAMETERS

A. Unique characteristics of VANET:

Even though, Vehicular ad hoc networks are the subset of MANET community and a component of ITS, it has its own unique characteristics due to its high mobility. These characteristics [15] may include,

a) Dynamic Topology**:** The participating nodes in VANET are the vehicles. The speed and the path of these nodes always vary time to time, which creates a highly dynamic topology. For example, assume that two vehicles are moving away from each other with a speed of 25 m/sec and transmission range is about 250 m. Then, the link between these two vehicles will available only 5 seconds and immediately new topology will be created.

b) Communication Environment**:** The communication environment varies from highways to city environment. Highway environment is simple and predictable due to one-dimensional model. But the city environment will be very complex and too difficult, due to the street structure, variable node density, presence of buildings and trees. The node prediction design and routing algorithm should consider all the factors into account to design the mobility model.

c) Mobility Modeling**:** For a mobility model, prediction of node position, the predefined model for roadways and the speed of vehicle are very important for effective network design. Since VANET has highly dynamic topology, the position and the movement of any vehicle node is difficult to predict.

d) No Longer Connectivity**:** Generally, the nodes are linked with nearby nodes to maintain seamless connectivity for longer communication. But in VANET frequent disruption of network connectivity will occur. Such problems can be dealt with road-side deployment of relay nodes.

e) Time-Sensitive Data Exchange**:** Most of the safety applications require data packet transmission in a timely manner. These data should be transmitted in time to avoid harms on the road.

***f) Anonymous Addressee*:** Most applications in VANET require identification of the vehicles in a certain region, instead of the specific vehicles. This may lead security problems in VANET.

***g) On-board Sensors Interaction*:** This sensor helps in providing node location and their movement nature, for effective communication link and routing process.

B. Factors affecting performance of VANET:

Robust message dissemination is one of the challenging tasks which are indispensable for various VANET applications. The dominating performance factors that affect the VANET performance are

***a) Network size*:** Network size refers to the number of source destination pairs engaged in data transfer. For example, among 100 nodes, 15 source nodes and 15 destination nodes (i.e. 30 nodes in total) will be engaged in data transfer. However, during this data transfer process, the other 70 nodes will be operated in the background. This may provide necessary support for forwarding and routing in the ongoing communication process.

***b) Node pause time*:** It refers, the rest time of the node or the time between the changes in direction or speed. A node begins by staying in one location for an indefinite period of time. This is called pause time and once this time expires, the node chooses a random destination.

***c) Node speed*:** Node speed refers to the average speed with which nodes move in the simulation area.

***d) Network connectivity*:** Network connectivity is a critical metric for planning, designing, and evaluating the ad hoc network. The Percentage of network connectivity indicates the probability of finding a source–destination path between any two nodes for a given network density and mobility level.

***e) Average Hop Count*:** It is the averaged hop count of a mobile path for a source–destination session. Many sessions for the same source-destination path are taken into account for averaging the hop count. The minimum hop paths determined under the urban mobility model are relatively more stable and have a larger route lifetime.

***f) Routing Protocol*:** A routing protocol plays an important role for the overall performance of mobile ad hoc networks. For instance, the results of [17] shows that Dynamic Source Routing (DSR) is suited for small and low mobility networks and Ad hoc On-Demand Distance Vector (AODV) perform better for medium sized networks under high traffic loads.

C. Performance Metrics:

To study the performance of various data dissemination protocols, the suitable performance metrics must be identified. In general, the following metrics are suitable to evaluate the efficiency of a data dissemination protocol.

***a) Delivery time*:** defines how soon the message can be delivered to the intended receiver.

***b) Packet Delivery Ratio (PDR)*:** Packet delivery ratio is the ratio of the number of packet received by the destination to the number of packet sent by the sender. It may affect by different crucial factors such as packet size, group size, action range and mobility of nodes. The robust message transmission is defined as the 100% packet delivery, where the receiver receives all the packets sent by the sender with in the time duration.

***c) Bandwidth*:** In VANET, bandwidth utilization is more as compared to other wireless networks due to high mobility of nodes. In [18], author estimated the bandwidth consumption from the interference range of the nodes. The utilization of bandwidth has tremendous impact on system performance. In both, under-estimated and over-estimated systems performance decreases due to inaccurate estimation.

***d) Packet overhead*:** includes both the control and data packet overhead.

***e) Data latency*:** It means, the time duration between issuing a message from sender until it is received by receiver. An important parameter to be considered in sending and receiving a data packet is transmission time delay, through which the throughput rate is calculated.

Authors in [19], focused on finding the routing path that has the maximum link reliability and a link delay less than an embarrassed bound.

IV. PERFORMANCE REVIEW DATA DISSEMINATION PROTOCOLS

Data dissemination is the art of transporting messages to a number of intended recipients based on different situations. Many existing protocols proposed various interesting approaches for data dissemination in VANET. Starting with flooding, data dissemination process met dramatic developments like push-pull technique, carry-forward technique, based on swarming[9], cluster based[10], vehicle assisted [11] and so on.

The following section reviews a set of protocols which are most interesting and expected to impact the data dissemination field in great level.

A. Content Based Dissemination:

The main objective of this content–based dissemination protocol [20] is to design a protocol which would be able to disseminate different types of events with minimum bandwidth utilization and limiting the exchange of messages. It supports different dissemination modes as follows and maintains a suitable dynamic area.

a. Diffusion of an accident is to be only to the vehicles driving in its own direction.
b. Diffusion of an emergency braking is to be only the vehicles moving in a particular direction.
c. Information like available parking slot, hot places etc are to be diffused only to the interested vehicles.

The approach was with Encounter Probability (EP), which represents the probability that a vehicle meets a certain event. It is calculated as

$$EP = 1 / (\alpha*\Delta d + \beta*\Delta t + \gamma*\Delta g + \zeta*c + 1)$$

Where α, β, γ, and ζ are penalty coefficients with values≥ 0. In practical cases, $\alpha + \beta + \gamma + \zeta > 0$; otherwise, the EP always equal to 1.

For a certain vehicle, if the EP of an event is high, then the event could be considered particularly relevant for the vehicle because it is likely to encounter that event. Based on this idea, each vehicle could decide dynamically whether the received information about an event should be re-diffused or not. This also guarantees the maintenance of relevant of information to close enough during the dissemination phase.

Implementation has been done using Vehicular Event Sharing with a mobile P2P Architecture (VESPA) system and values are extracted using OPNET network simulator.

Experiments are repeated for 10 times and the average values are taken into account. The result shows that the approach limits the number of messages exchanged which is better than the results by traditional flooding and periodic flooding. This approach also stores the information about an event until, the event becomes irrelevant. It is resulted that this approach of data dissemination could be deployed into any type of vehicular application.

B. Buffer Based Dissemination:

In Bloom Filter based Buffering Data Dissemination (BFBD) algorithm [21], the authors propose BFBD with Mobility Induced Redundant Transmission (MIRT) by using decayed bloom filter. The bloom filter is the structure, to record the data dissemination history and handles the intermittent-connectivity mechanism.

Bloom filter is a space-efficient probabilistic data structure that is used to test whether an element is a member of a set.

It composes of two parts:

(i) A bit array with μ bits,

(ii) K hash functions: h1(m), h2(m) … h_K(m).

Where each hash function maps an element to an index value within the range [1, μ]

The BFBD Algorithm is developed with

(i) A decayed bloom filter,

(ii) Local buffering of packets and

(iii) Local buffering of bloom filter.

The history of data dissemination is recorded in bloom filter. To handle the intermittent-connectivity, local buffering of packets is implemented. The buffering scheme supports the following circumstances with correct packet dissemination.

a. While the vehicle node joining with other clusters even though it has been covered by all its neighboring vehicles.
b. Even after forwarding packets, a node can participate in data dissemination to new nodes of cluster in future.

The algorithm uses local buffer whose element is a 4-tuple <*dd_src, dd_seq, packet, bloom_filter*>. When a node *n* receives a packet *p,* it first checks whether there are neighbors within the destination region. If none of its neighbors are within the destination region, the node simply drops the received packet. Otherwise, it checks whether all its neighbors are contained by the merged bloom filter, which represents the dissemination history. If all its neighbors have been covered by the dissemination history, it buffers the packet and does not forward for this time. As long as there are non-covered neighbors, the packet is forwarded immediately.

The simulation environment is NS2 and the simulator VanetMobiSim is used for mobility trace analysis. In terms of reliability, dissemination efficiency and delay, it has been proved that the performance of BFBD is superior over contrastive algorithms.

C. Agent Based Dissemination:

The authors of [22] proposed a model by using cognitive agent concept for realizing intelligent information dissemination. They showed that using software agents including cognitive and mobile agents, vehicles autonomously collect, classify and disseminate critical information. The proposed agent framework is based on push-pull concept for critical information gathering and dissemination. For critical events, proposed scheme takes appropriate decisions as and when required.

Using push approach, the critical events like accidents, heavy rain and fog are detected. Using pull approach, the non-critical applications like road conditions, vehicle speed and internet accesses are detected. This logic proves that efficient bandwidth utilization is achieved.

The cognitive agent model uses the following procedural steps:

a) Generate VANET in given road length by placing vehicles uniformly.

b) Maintain a data structure at each vehicle to store information as specified by scheme.

c) Apply mobility to nodes.

d) Generate cognitive agency.

e) Compute performance of system.

The performance metrics like bandwidth utilized, packet delivery ratio, push latency, push/pull decision latency are evaluated using NS2 network simulator. It has been showed that the bandwidth utilization increases linearly as the number of vehicles increases and remains constant for constant number of vehicles on the road.

Also it has been proved that push/pull decision latency increases as the number of sensors increases, linearly and remains constant for large number of sensors.

D. Coding Based Dissemination:

A novel scheme, called Data Dissemination using Rate less Code (DDRC) for collaborative content distribution from road side units to vehicular networks is proposed in [23]. This approach uses the vehicular model as shown in Figure 2 in which the vehicles on the road can be divided into two groups

(i) *Collectors:* These are the vehicles that are approaching toward a specific RSU.

(ii) *Carriers:* These are the vehicles that have been successful in decoding a specific RSU's message.

When a message arrives at a RSU, the RSU converts the message into smaller data packets. These packets are then encoded into a set of slightly bigger size using the described rate less encoding scheme. Then the RSU broadcasts the set of encoded packets. The collector collects the encoded packets and carries the packet towards the next RSU. Collector vehicles switch to become *carrier* after they pass an RSU.

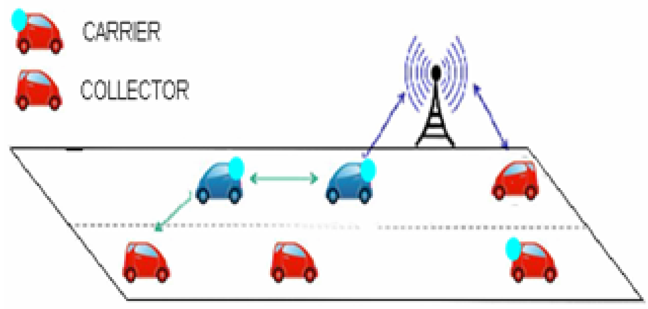

Figure 2 DDRC Model

This approach also uses decoding distance and deployment capacity for performance evaluation and provides an analytical model to explore them. The performance of the system was simulated with NS-2 network simulator.

The presented models capture the effect of various parameters in the network and provide guidelines on choosing the parameters to maximize the performance. This approach guarantees robustness at the infrastructure level and addresses some of the observed issues such as link instability and packet losses. The proposed scheme also can handle both sparse and dense scenarios.

E. Priority Based Dissemination:

In [24] the authors proposed priority based inter-vehicle communication in VANET using IEEE 802.11e standard. They allotted different priority levels for safety messages under the following conditions.

a. All vehicles move fast, thus, it can cause high bit error rates.
b. All vehicles move in the same direction, following the road topology.
c. The safety messages to be communicated have a few hundred bytes and have different priorities.

Table: 1Priority based messages.

Type of Message	*Priority*
Accident Messages	Pri(1)
Possibility of accident	Pri(2)
Warning Messages	Pri(3)
General Messages	Pri(4)

They attempted transmission of messages repetitively which is based on the priority of a message.

Table I shows the messages and their priorities allotted based on the type of message.

To increase the probability of a successful transmission of high priority messages it is transmitted more times than a lower priority message. Each priority level of safety message is mapped to a different traffic class of IEEE 802.11e. This supported MAC protocol, fully compatible with both IEEE 802.11 and IEEE 802.11e standards.

Simulation studies have been done using OPNET modeler and the performance was investigated as the function of number of repetitions, number of vehicles, percentage of priority-1 vehicles and packet size. The result shows that the proposed approach leads to high normalized throughput and low transmission delay even when the number of vehicles is high and the traffic load is heavy.

Table: 2 Comparative Analyses of Dissemination Protocols for VANET Scenario

Protocol	*Approach*	*Performance Metrics used*	*Simulation*	*Results*	*Suitable for*
Content–Based dissemination protocol [27]	Encounter Probability	Bandwidth	VESPA & OPNET	Limits the bandwidth utilization	Any type VANET application
Bloom Filter based Buffering Data Dissemination (BFBD) algorithm [29]	Mobility Induced Redundant Transmission (MIRT) with Bloom Filter	Reliability, Efficiency & Delay.	NS2 and VanetMobiSim	The performance of BFBD is superior over contrastive algorithms.	Reliability sensitive data dissemination
Agent based Intelligent information dissemination [31]	Software agents with Push/pull approach	Bandwidth, & latency	NS2	Best bandwidth utilization & latency based on number of vehicles & sensors respectively	VANET to autonomously collect, classify and disseminate critical information.
Using Rateless Codes-DDRC [32]	Collector/Carrier with rateless code	Data delivery Ratio	NS2	Minimize the packet losses and maximize the performance metrics	Both sparse and dense scenarios.
Priority based [33]	Safety messages with different priorities and Repetition	Throughput & Delay	OPNET	High normalized throughput and low transmission delay	Any type VANET application

V. COMPARATIVE ANALYSIS OF DISSEMINATION PROTOCOLS

The features of various data dissemination protocols were summarized in Table II.

It shows the approach for dissemination, the performance metrics used, the simulation platform used for evaluation. The performance metrics used and the simulation platform used for evaluation. The overall result of each approach was also given. It also highlights the application scenario for which the concern approach is suited.

Content based approach limits the number of messages exchanged and produces better results than by traditional flooding and periodic flooding and this approach of data dissemination could be deployed into any type of vehicular application. Using bloom filter the reliability, efficiency of dissemination are improved and proved that the performance of BFBD is superior over contrastive algorithms. The bandwidth utilization increases linearly as the number of vehicles increases. By coding techniques the performance of protocols can be maximized and can handle both sparse and dense scenarios. The priority based system reduces the transmission delay and increases the throughput even though the traffic load is high.

VI. CONCLUSION

From the analysis, it is concluded that, most of the protocols concentrate to increase bandwidth utilization and data delivery ratio. NS2 network simulator is the best simulation environment along with some tracing tools and mobility models. VanetMobiSim is the best suited mobility model generator for vehicular network scenario.

The selection of data dissemination technique depends on the type of application, road environment, vehicle condition and type of data to be disseminated. An investigation is in progress to design a best data dissemination protocol to improve quality of service parameters in tremendous way.

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