ISSUES AND CHALLENGES IN BROADCAST STORM SUPPRESSION ALGORITHMS OF VEHICULAR AD HOC NETWORKS

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ABSTRACT

__V__ehicular __A__d-Hoc __Net__works (VANETs) are the networks of vehicles which are characterized with high mobility and dynamic changing topology. Most of the communication interchanges in VANETs take place in broadcasting mode, which is supposed to be the simplest way to disseminate (spread) emergency messages all over the vehicular network. This broadcasting technique assures the optimal delivery of emergency messages all over the VANET. However, it also results in unwanted flooding of messages which causes severe contention and collisions in VANETs leading to __B__roadcast __S__torm __P__roblem (BSP) and in turn affects the overall performance of VANETs. A Multitude of research work have proposed Broadcast Storm Suppression Algorithms (BSSA) to control this Broadcast Storm. These mechanisms tried to control BSP by either reducing the number of rebroadcasting/ relaying nodes or by identifying the best relay node. The suppression mechanisms help to overcome BSP to certain extent, still there is need to still reduce the number of rebroadcasting nodes in existing mechanisms and also to identify the best possible rebroadcasting node. This would help to mitigate BSP completely and efficiently. This paper presents a comparative analysis of various prominent BSSA in order to identify the underlying issues and challenges in controlling BSP completely. The outcome of this paper would provide the requirements for developing an efficient BSSA overcoming the identified issues and challenges.

KEYWORDS

VANET, BSP, Broadcast Suppression, Data Dissemination

1.INTRODUCTION

A Vehicular Ad hoc Network (VANET) is a collection of vehicles communicating through wireless technology to improve road safety[1]. In VANET, every vehicle is equipped with wireless communication infrastructure which could collaboratively disseminate data about any road activity (viz. accidents, traffic jams, road construction warning, shadowing effect, bad weather condition etc.) to other vehicles inside a Range of Broadcast (ROB) area [2]. The Data Dissemination (communication among participant vehicles) in VANET within ROB is mostly carried out through "Broadcasting" technique which could be as follows [3]:

1. **Simple Broadcasting**: The messages are simply broadcast to all the vehicles in the network without using any BSSA. It is also referred to as blind flooding [4].

2. **Probabilistic and Delay based Broadcasting**: The messages are broadcast in a probabilistic manner based on a certain value of probability. The value of probability is calculated as a ratio between the distance of the sending &receiving vehicle and the average transmission range [5].

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3. **Area based Broadcasting**: The messages are broadcast based on the ROB of the transmitting and receiving vehicle locations. In this method, distance information is used to decide which nodes should rebroadcast [6].

4. **Neighbour Knowledge based Broadcasting***:* The messages are broadcast based on the knowledge of the neighboring nodes. In this method the vehicle needs to share 1-hop or 2-hop neighborhood information with other nodes via periodic exchange of hello messages to decide on the next forwarding node. However, this method is not suitable for vehicular environments since messages become outdated due to the high mobility of vehicles [7].

These four types of Broadcasting help to reduce the road accidents and alert the drivers about any emergency event in a particular area, thereby securing the safety in road transport [8]. Broadcasting assures for optimal delivery of emergency messages, by transmitting them redundantly. This redundancy is a resultant of blindly broadcasting the same message in a ROB to ensure its optimal delivery. However, this kind of blind broadcasting of ESM may lead to severe contention and collisions within a ROB and this triggers for a Broadcast Strom Problem (BSP).The Broadcast Strom Problem occurs when multiple vehicles attempt to transmit the ESM at the same time, thereby causing high data traffic, network congestion, message collisions, service disruption and extra delay in VANET [9]. The performance of VANET gets affected due to BSP.

Existing Research proposed various Broadcast Storm Suppression Algorithms (BSSAs) to mitigate BSP. Majority of these algorithms suppress Broadcast Storm by reducing the redundancy of rebroadcasting messages either by limiting the number of rebroadcasting/relay nodes or identifying the best rebroadcasting nodes. However, prominent BSSA poses certain issues and challenges in reducing the number of rebroadcasting nodes in ROB and identifying the best possible relaying node. These issues and challenges have to be addressed by which BSP is thwarted completely and effective performance of VANET is ensured.

This paper is motivated to analyze the existing BSSAs along with their strategies in mitigating BSP and also their limitations. The inference perceived from this comparative analysis would help to draw the requirements for proposing an efficient BSSA that could enhance its scalability, reliability, reachability, dissemination time etc. in a VANET, thereby reducing the number of rebroadcasting nodes and identifying the best possible broadcasting node.

The remainder of this paper is organized as follows: Section 2 presents an overview of Broadcasting techniques and Broadcast Storm problem. Existing BSSA and their classification are discussed in Section 3 which details about Probabilistic, Timer and Locations based Techniques and the prominent works available. A Comparative analysis and summary of Probabilistic, Timer and Location based techniques are presented in Section 4. Section 5 discusses about the Outcome of the comparative analysis and finally the paper concludes with pointers for further research.

2. BROADCAST STORM PROBLEM (BSP)

Broadcast communication is unreliable in VANET due to the lack of acknowledgements in CSMA/CA mechanism present in the IEEE 802.11p standard [10]. The vehicular safety application is improved by broadcasting a safety alert message in an emergent event for preventing the accidents or to give the prior intimation to the drivers about the dangerous situation [11].

In VANET, when multiple nodes available in the same transmission range (ROB) re-broadcast the same message, then severe contention (contend for the channel) will occur that would lead to collisions in the MAC layer [12]. This scenario is referred as Broadcast Strom Problem (BSP) as shown in Figure 1. The circle in figure 1 represents the storm of rebroadcast messages. In this figure each node initiates the rebroadcasting operation randomly. All the vehicles will contend for the channel access; it creates severe congestion and collision.

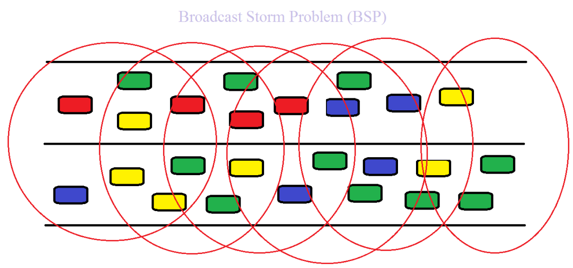

Figure 1. Broadcast Storm Effect in high density VANET

2.1. BSP in Simple Flooding

BSP was very much prevalent in Simple Flooding Broadcast technique. According to flooding technique, whenever a node receives an emergency message it will re-broadcast it to all other nodes in the VANET [13]. This could result in redundant re-broadcasts because the neighbors of the re-broadcasting node may already have received the same message especially in a dense network scenario [14]. Since, this technique doesn't facilitate for CTS/ RTS (Clear To send / Read to send) and Collision Detection strategies, the available channel bandwidth is wasted by sending redundant frames that will probably collide [15]. However, the other broadcasting methods (discussed next) provided improved control over BSP.

2.2. BSP in Probabilistic and Delay based Broadcasting Technique

Probabilistic and Delay based Broadcasting technique does not recommend for rebroadcasting an emergency message to all nodes available in a ROB. By this method, the nodes present at borders of a ROB have the highest probability to be the next rebroadcasting node [16]. By this, the number of rebroadcasting nodes get reduced thereby reducing BSP when compared to Simple Flooding. However, if the number of nodes present at the Border of ROB is very much high, then the situation is similar to Simple flooding.

2.3. BSP in Area based Broadcasting Technique

Area based Broadcasting techniques overcome the above said issue in Probabilistic based broadcasting, by identifying a single node (Farthest node) within a ROB to rebroadcast the ESM further [4]. However, this method relies completely upon GPS information to identify the farthest node. GPS information may or may not be available and the information may be inaccurate many times. Hence it is important to substantiate the position of the farthest node via an alternative methodology [17].

2.4. BSP in Neighbour Knowledge based Broadcasting

In neighbour knowledge based information broadcasting, the rebroadcast node is identified by a sender by acquiring its information prior to its assignment. This method requires 1-hop, 2-hop or n-hop neighbourhood information [6]. Similar to Area based broadcast technique; this methodology also relies on GPS information. However, this method is not suitable for vehicular environments since messages become outdated due to the high mobility of vehicles.

In summary, the above explained broadcasting techniques showcased their strength and limitations in suppressing BSP. The BSP should be reduced to improve the emergency data dissemination efficiently and in a timely manner. The Emergency Safety Message (ESM) in vehicular networks should reach within fraction of seconds without any delay or message loss to improve the road safety in the ROB. The main requirements in broadcasting techniques are to improve the reliability of message dissemination, to decrease dissemination delay time and to increase the message delivery ratio [18] .These requirements are achieved only by reducing the number of rebroadcasting nodes in a ROB and identifying the best possible rebroadcasting node.
The unnecessary redundant rebroadcasting of the ESM triggers the need for Broadcast Storm Suppression Algorithms (BSSAs). The main working principle of major BSSAs is to curb the rebroadcasting as maximum as possible. Next section details about the major classifications of BSSAs and prominent works that are available in every classification is discussed.

3. BROADCAST STORM SUPPRESSION ALGORITHMS (BSSAS)

Broadcast Storm Suppression Algorithms are defined as the methodologies that aim to decrease the number of rebroadcasting nodes so as to reduce the redundant packets and mitigate the broadcast storm problem [19].The ultimate goal is to select only the set with the minimum number of vehicles to rebroadcast and disseminate a message towards the ROB [20]. BSSAs can be classified based on the different types of broadcasting techniques as given in the introduction of this paper. The following figure 2 shows the taxonomy of BSSAs.

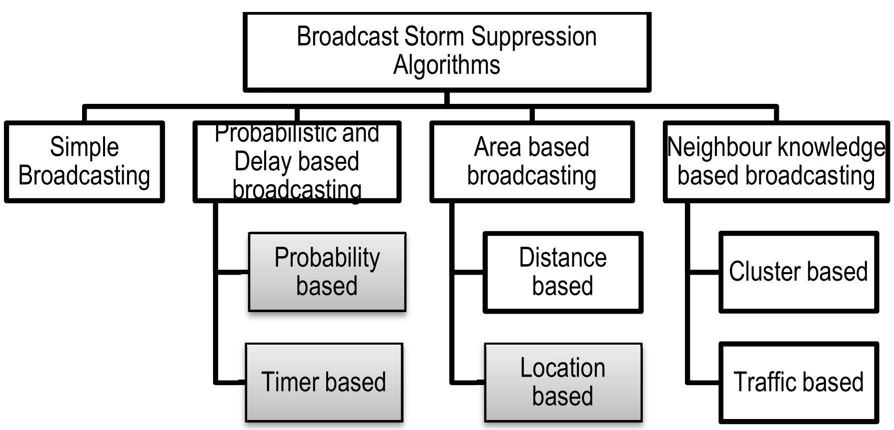

Figure 2. Taxonomy of Broadcast Storm Suppression Algorithms

The shaded portions in the given classification represent prominent BSSAs which are majorly applied in many VANETs to suppress BSP [20][21][22][23][24]. These algorithms are studied in depth to understand their working strategy used to suppress BSP along with strengths and limitations. Following sub-sections narrates the selected BSSAs in detail.

3.1 Probabilistic Suppression Algorithms (PSAs)

Probabilistic suppression algorithms try to suppress BSP by broadcasting ESM only to selected nodes based on a 'value of probability'. The 'value of probability' identifies the rebroadcasting nodes based on their availability at border locations in a ROB. The highest probability is assigned to nodes that are at very farthest position from the sender node [5]. The following are some of the noticeable works based on the PSAs.

- Weighted p-Persistence Broadcasting Algorithm (WPB)
- Adaptive Probability Alert Protocol (APAL)
- Probabilistic Inter Vehicle Geocast (p-IVG)
- The Nth Powered P-persistent Broadcast Protocol (NPPB)

The explanations of these algorithms are as follows:

3.1.1Weighted p-Persistence Broadcasting Algorithm (WPB) [25]

This algorithm works with the basic principle of forwarding the ESM to a node based on a value of probability (P_{ij}) which is defined to be the ratio between the relative distance D_{ij} from the source node (i) to another node (j) and average transmission range (R). When the node j receives ESM from i for the first time, then it rebroadcasts the ESM with forwarding probability P_{ij} which is calculated per packet basis. In addition, the node j discards the repeated reception of ESMs. The figure given below shows the worki ng of WPB algorithm.

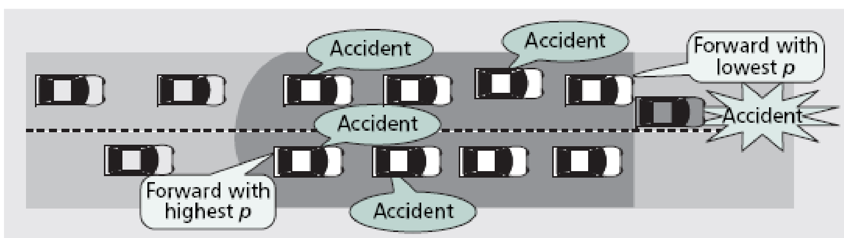

Figure 3. Weighted p-Persistence Broadcasting [25]

In this algorithm, the number of rebroadcasting nodes proportionally depends on the density of the traffic available at Border of ROB. Hence, the best possible rebroadcasting node(s) always would be greater than a single node. This may lead to redundancy of ESM rebroadcasting.

In summary, WPB tries to reduce the BSP by using probability to decide the vehicle that will rebroadcast the ESM. However, vehicle density is not considered in WPB. For e.g. when the distance between any two nodes are very near, then both will rebroadcast the message at the same probability and both will increase the broadcast storm rate.

3.1.2 Adaptive Probability Alert Protocol (APAL) [26]

According to this Protocol, the accident vehicle (AV) broadcasts an ESM (during an accident) to all the other vehicles which are moving in the same direction as of the AV. A vehicle that has received the ESM initially waits for a random time Δt. At the expiry of Δt, the vehicle checks whether it has received the same ESM from some other source. If yes it discards the ESM otherwise it rebroadcasts the ESM with high probability to the vehicles at ROB. Figure (4) illustrates the working of APAL.

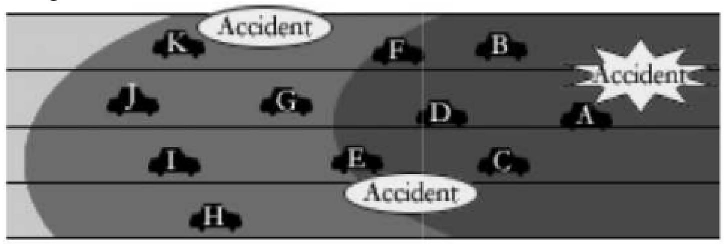

Figure 4. Adaptive Probability Alert Protocol [26]

In summary, APAL controls BSP efficiently than WPB by introducing the concept of waiting time along with the value of probability. However, the randomness of waiting time meant for multiple sources have a risk of duplication of ESMs.

3.1.3 Probabilistic Inter Vehicle Geocast (p-IVG) [27]

Probabilistic Inter Vehicle Geocast is a BSSA algorithm that considers vehicle density of VANETs to control BSP. *p*-IVG adapts itself according to the current traffic density to minimize the number of vehicles to re-broadcast the received message at the same time minimizing the probability of failing to re-broadcast the received message. The vehicle density is detected through a light-weight local topology sensing utility. In IVG, each vehicle starts a timer for each ESM it receives. If the timer expires and the ESM associated with this timer has not been rebroadcast by any other vehicle within ROB, the vehicle re-broadcasts ESM. The timer value T_x for vehicle *x* is

$$T_x \quad = \mathrm{T}_{\max}.\frac{\left(\mathrm{R}^{\epsilon} - \mathrm{D}_{\mathrm{sx}}^{\epsilon}\right)}{\mathrm{R}^{\epsilon}}$$

where *R* is the transmission range and D_{sx} is the distance between vehicle *x* and vehicle *s*, the sender of the ESM. This algorithm improves packet reception rate and channel contention. When a vehicle receives a new ESM, it first selects a random number between [0, 1]. When the selected number is less than 1/vehicle density, the timer will be started otherwise ESM will not be rebroadcasted by this vehicle.

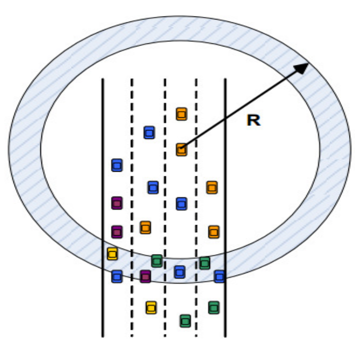

Figure 5. Probabilistic Inter Vehicle Geocast [27]

However, in this algorithm BSP is controlled only in the border of ROB and BSP is not controlled within ROB.

3. 1.4 The Nth Powered p-Persistent Broadcast Protocol (NPPB) [28]

This algorithm is similar to WPB. This algorithm allows rebroadcast nodes to concentrate towards the border of the source node's coverage area, which will increase the additional coverage area of the next hop with less rebroadcast. P_i (value of probability) is calculated based on the value of 'n' which is not available in WPB. By this new probability, the rebroadcasting redundancy is controlled.

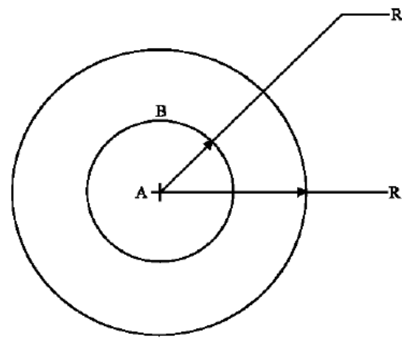

Figure 6. NPPB [29]

The following formula provides the calculation of P_i.

$$P_i = \left[\frac{L_{ij}}{R}\right] n \times 100\%$$

This algorithm improves the source nodes coverage area by minimizing the rebroadcasting nodes. However similar to WPB the border nodes will increase the collision rate.

Thus the Probability Suppression Algorithms (PSAs) tries to control BSP based on the value of probability, but mostly do not consider the vehicle density.

3.2 Timer based Suppression Algorithms (TSAs)

TSA algorithms broadcast ESM to particular nodes that are available within a slot defined in ROB. ROB is divided into multiple slots based on the geographical area. By dividing the slots, the vehicle density problem available in PSAs is limited. The slots near ROB have highest priority to receive ESM for further rebroadcasting. The following list presents certain major works based on this principle.

- Slotted 1-Persistence Algorithm (SOB)
- Slotted p-Persistence Algorithm (SPB)
- Distributed Optimized Time (DOT)
- Adaptive Multi-directional Data Dissemination (AMD)
- Time-Slotted Multi-hop Broadcast Protocol (TSM)
- Virtual Slotted p-Persistence Broadcasting (VSPB)
-

3.2.1 Slotted 1-Persistence Broadcasting Algorithm (SOB) [25]

In SOB upon receiving a ESM , a vehicle checks the ESM ID and rebroadcasts with probability 1 at the assigned time slot (T) if it receives the ESM for the first time and has not received any duplicates before its assigned time slot; otherwise it discards the ESM.

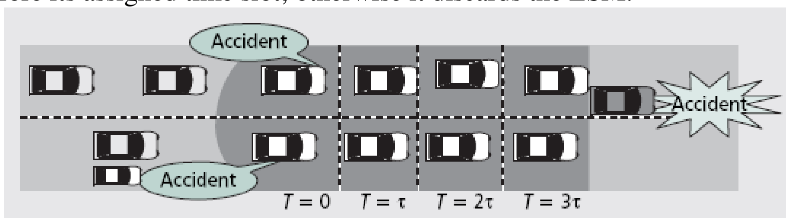

Figure 7. Slotted 1-Persistence Broadcasting [25]

$$S_{ij} = N_s \left[1 - \left\lceil \frac{min(D_{ij}, R)}{R} \right\rceil \right]$$

3.2.2 Slotted p-Persistence Broadcasting Algorithm (SPB) [25]

In SPB, upon receiving a ESM a vehicle checks the ESM ID and rebroadcasts with the pre-determined probability 'p' at the assigned time slot, if it receives the ESM for the first time and has not received any duplicates before its assigned time slot; otherwise it discards the ESM.

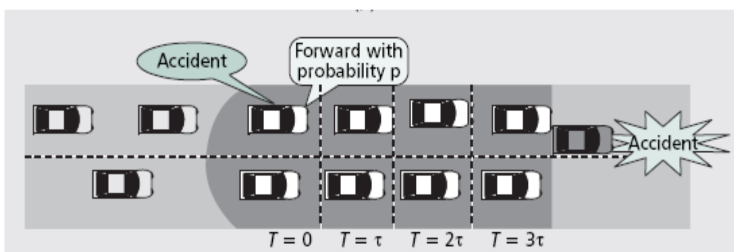

Figure 8. Slotted p-Persistence Broadcasting [25]

[25] The drawback of both these schemes are: In dense scenario, multiple vehicles may rebroadcast the message simultaneously and causes severe collisions. In sparse network scenario it increases the waiting time (slot with empty nodes). In [44] the performance of SPB is highly dependent on the vehicle density and distribution.

2.2.3 Distributed Optimized Time (DOT) [30]

[30] DOT solves the scalability issues in the presence of beacons and periodic hello messages to provide cooperative awareness in safety applications. It uses GPS receiver to know the one hop neighbors within it transmission range. The ESM header contains the following details Vehicle ID, Message ID, Time Stamp, Vehicle's Geographical Coordinates, Power Level.

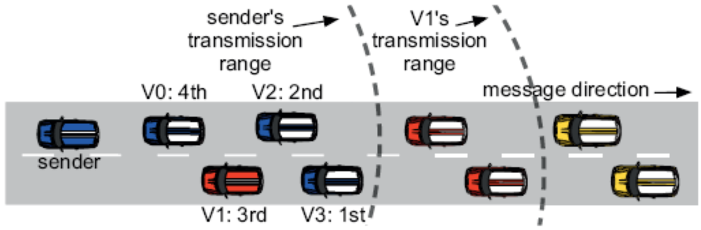

Figure 9. DOT [30]

3.2.4 Adaptive Multi-directional Data Dissemination (AMD) [1]

The infrastructure-less Adaptive Multi-directional data Dissemination (AMD) protocol proposed in [1] works both in highway and urban scenarios. There are two types of messages generated namely data message and beacon message. The data messages are transmitted at the time emergent event and the beacon messages are transmitted at a certain interval. These messages consist of data rate, channel number, and the transmission power level employed and position, speed, and acceleration. Each vehicle is required to include a message list in their beacons, containing their last *k* data messages received to prevent loops in the network.

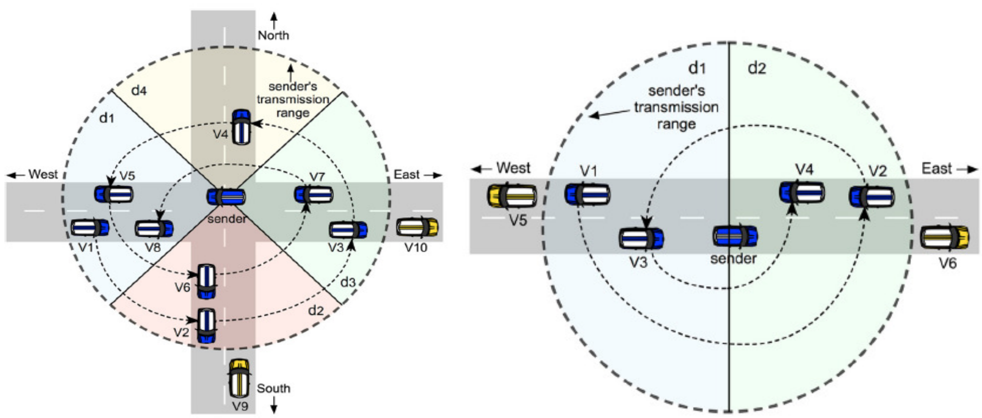

Figure 10. AMD [1]

3.2.5 Time-Slotted Multi-hop Broadcast Protocol (TSM) [22]

Time-Slotted Multi-hop Broadcast Protocol (TSM) [22] proposed to avoid BSP by selecting only a subset of vehicles on the road to serve as the relay node. The segment leader is responsible for forwarding the warning messages in its road segment. TSM allocates separate time slots for the warning messages to avoid interfering with the safety messages. The signaling mechanism ensures the reliable delivery of the multi-hop messages. In TSM each vehicle is equipped with a differential global positioning system (DGPS) to measure its position on the road.

This algorithm introduces the following new features: (i) segment leader based message forwarding approach to reduce the number of relay vehicles. (ii) Separate multi-hop time slots are allocated for the warning messages to overcome the interference with the single-hop safety message (iii) Handles the scenario of lost acknowledgment (ACK) by the unnecessary retransmissions of the warning messages and improves reliability through receiving ACK.

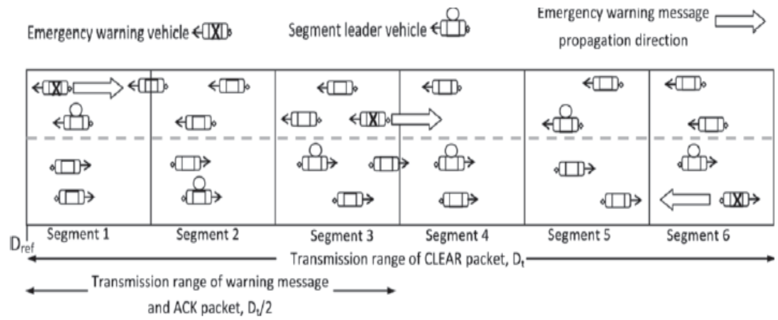

Figure 11. Warning Message Dissemination in TSM on highway [22]

3.2.6 Virtual Slotted p-Persistence Broadcasting (VSPB) [31]

Virtual Slotted p-Persistence Broadcasting (VSPB) technique is proposed in [31]. In VSPB the number of vehicles in a slot can be controlled regardless of the vehicle density and distribution. In sparse network, the proposed scheme can avoid unnecessary waiting before rebroadcasting by eliminating the empty slots that occur with the slotted *p*-persistence scheme [3]. In the virtual slotted *p*-persistence scheme, upon receiving a ESM, a vehicle checks the ESM ID and determines its virtual slot number and waiting time. If the ESM is received for the first time and the vehicle does not receive any duplicates before its assigned time slot, it then rebroadcasts using the probability *p* at the assigned time slot. If no vehicle in a previous virtual slot rebroadcasts the ESM, the vehicles in the next virtual slot rebroadcast the ESM using probability *p*.

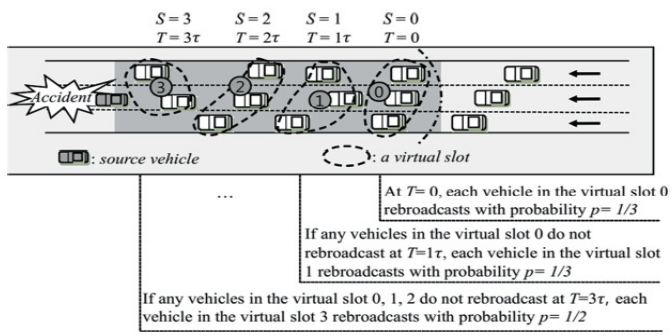

Figure 12. Virtual Slotted p-Persistence Broadcasting [31]

The VSPB uses hello messages to periodically exchange basic information between any two vehicles. Each vehicle maintains its own neighbor table through the received hello messages. The number of neighboring vehicles can be easily obtained from its neighbor table. The hello message consists of vehicle ID, position information, and moving direction. The grouping is formed by position information and moving direction of the vehicle in its neighbor table. This kind of grouping is called as virtual slot. After receiving the ESM, each vehicle in the virtual slot rebroadcast the ESM which will increase the collision.

3.3 Locations based Suppression Algorithms (LSAs)

The following are majority of LSA to solve the effect of BSP in accident zone.

- Adaptive approach for Information Dissemination (AID)
- Relative Position based Message Dissemination (RPB-MD)

- A Data Dissemination (ADD)
- Data dissemination pRotocol In VEhicular networks (DRIVE)
- Automatic Dissemination Method (ADM)

3.3.1 Adaptive approach for Information Dissemination (AID) [32]

Adaptive approach for Information Dissemination (AID) proposed in [32] allows nodes to efficiently rebroadcast received messages. AID selects an appropriate action (re-broadcast or discard) in a distributed manner without the aid of a central controller. In AID, each individual vehicle can dynamically, based on the number of ESM received from its neighbors, decide on rebroadcasting. On receiving an ESM for the first time, the vehicle initializes a local counter c to 1 to keep track of the number of times the ESM is received and waits for a random number of slots t. Another counter s, initialized to 0, is used to help vehicles for deciding on the rebroadcast. AID [33] protocol is not suitable for intermittently connected network problem.

The speed of vehicles is fixed to 1, 5, 15, and 25 m/s and the number of vehicles is fixed to 25, 50, 100, and 150, respectively. At a crossover, vehicles choose to turn left or right with equal probability, 0.5. At an intersection of a horizontal and a vertical street, each vehicle chooses to keep moving in the same direction with probability 1/2 and to turn left or right with probability 1/4.

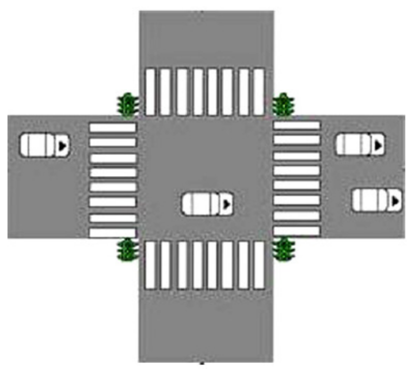

Figure 13. Structure of each Intersection [32]

3.3.2 Relative Position Based Message Dissemination (RPB-MD) [34]

The Relative position based addressing model is proposed in [34]to ensure robust message dissemination in VANETs. First, the Directional Greedy Broadcast Routing (DGBR) is proposed to make a group of upstream vehicles hold ESM to improve the dissemination reliability. Second, it can adjust the time parameters intelligently according to the ESM attributes and local vehicular densities. Finally, under various traffic densities, RPB-MD ensure that the ESM will be disseminated efficiently.

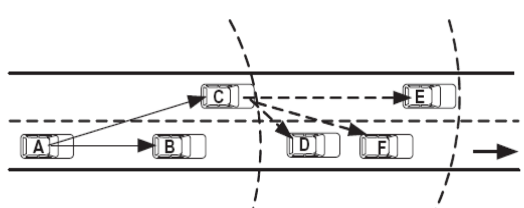

Figure 14. Directional greedy broadcast routing [34]

In RPB-MD, only the message head can forward the message, while the message holders can be the candidate message head. The message head goes through the following two phases: (i) The ‘‘Omni-directional Winner Rebroadcasting’’ which ensures the message is disseminated with the most progress. (ii) The ‘‘Back-Directional ACK Broadcasting’’ which acknowledges the old message holders that the message has been transmitted to another group successfully. In the forwarding process, RPB-MD forms a group of vehicles to carry and forward the message with no control message exchange. To improve the transmission reliability, all the message holders will carry this message with certain probability until some conditions are satisfied to drop the message.

3.3.3 A Data Dissemination (ADD) [35]

In [35] a data dissemination scheme is proposed to solve BSP in highway scenario. This protocol consists of two mechanisms: (i) broadcast suppression and (ii) delay desynchronization. It eliminates synchronization problem caused by 802.11p protocol. Because at each 100ms the control and service channels must be synchronized to receive safety related information and then back to control channel and vice versa. The preference zone is used to define an area in which the vehicles receive the message at a high rate. The algorithm is compared with AID, SRD and Simple Flooding using OMNT++ simulator under low, medium and high traffic conditions. The results show that ADD achieves 95% delivery ratio in dense case and it is 35% to 65% in simple flooding and 30% in other algorithms. It improves reliability in terms of high delivery ratio.

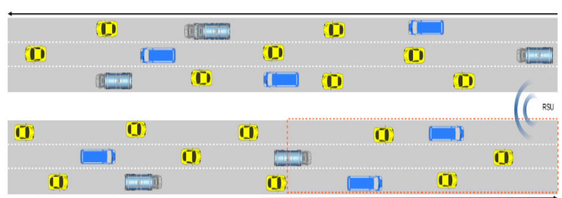

Figure 15. ADD Highway Scenario [35]

In ADD broadcast suppression is improved by reducing the collision rate to less than 40%, the less number of collision rate shows the broadcast storm suppression by utilizing the bandwidth efficiently. It improves delivery ratio up to 95% in dense highway scenario. The delay synchronization mechanism adds an extra time in transmission to eliminate the synchronization effect caused by 802.11p and it efficiently reduces the collisions to solve BSP.

3.3.4 Data dissemination pRotocol In VEhicular networks (DRIVE) [8]

In [8] a novel Data dissemination pRotocol In VEhicular networks (DRIVE) is proposed to solve BSP in VANET. DRIVE relies on local one-hop neighbor information to deliver messages under dense and sparse networks. In dense case, it selects vehicles inside a sweet spot to rebroadcast messages to further vehicles and employs implicit acknowledgements to guarantee robustness in message delivery under sparse scenarios. DRIVE eliminates the BSP and maximizes data dissemination capabilities across network partitions with short delays and low overhead [36]. A sweet spot is defined as an area in which its vehicles are best suited to continue performing data dissemination. Among all vehicles that received data to be forwarded, the transmission of a single vehicle within the sweet spot is sufficient to perform data dissemination efficiently. Vehicles located within the sweet spots are more likely to spread the message further and to reach a larger number of neighbors.

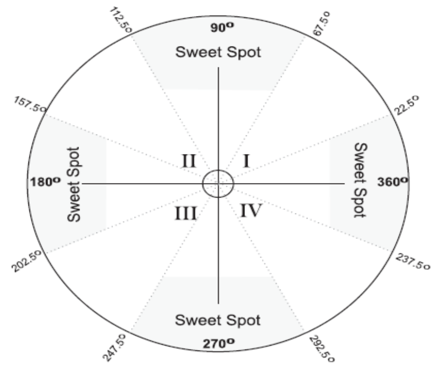

Figure 16. Sweet Spot Scenario in DRIVE [8]

3.3.5 Autonomic Dissemination Method (ADM) [37]

[37] Autonomic Dissemination Method (ADM) protocol delivers messages according to the message priority and network density levels. This scheme is based on (i) an offline optimization process and (ii) an online adaptation to the network characteristics. ADM allows each vehicle to dynamically adapt its broadcasting strategy with respect to the network density and priority of the message to send: ADM assigns high priority to emergency messages, medium-priority to road-traffic messages and low-priority to comfort messages. This algorithm increases the efficiency of the broadcast process in terms of message delivery ratio, latency and interferences reduction and improves the robustness of protocols.

In summary, the reviewed BSSAs use different methodologies to tackle BSPs. However, most of them rely upon GPS information alone to identify the farthest node(s). This poses severe drawback as GSP information may or may not be available and also may or may not be accurate. This motivates to compare the reviewed BSSAs based upon certain qualitative abilities that could help to identify the issues and challenges with respect to identifying the next rebroadcasting node. This would motivate for an efficient BSSA that could possibly identify the best possible farthest node.

4. COMPARATIVE ANALYSIS OF BSSAS

The reviewed BSSAs aim to disseminate ESMs with low propagation delay and without redundancy. They try to achieve this objective by different strategies as explained in previous sections. This section compares all the reviewed BSSAs with respect to certain qualitative abilities that are defined with respect to their performance in identifying the farthest node and reducing redundancy of ESM transfer. The qualitative abilities are considered from various work [6] which are defined as the requirements to be satisfied by a broadcasting technique. They are defined as follows:

4.1 Qualitative abilities used to analyze BSSAs [6][29]

Scalability: It is defined as the ability of the BSSA to handle high density scenario (More number of vehicles).This ability is also defined in terms of overhead required to transfer the ESM, the number of rebroadcasting nodes and also the redundancy ratio.

Robustness: It is defined as the ability of BSSA to cope with ESM losses in order to assure the correct functioning of vehicular safety applications. This ability is measured in terms of Packet Loss Rate (PLR) i.e. number of packets lost per unit of time.

Effectiveness: It is the qualitative attribute that ensures all vehicles at ROB receives the ESM.

Efficiency: This ability defines the quality attribute measured for a BSSA in terms of its capability to eliminate ESM redundancy. This quality attribute can be achieved by minimizing the forwarding rate, while assuring the reception of an ESM by all nodes in a specific geographic region.

Dissemination Delay: It is defined as the time ESM takes to be successfully received. It is measured by the following metrics:

- End-to-End Delay – Time taken by ESM to traverse from source to destination.
- Latency – Time taken by ESM to be successfully received by next vehicle.

Delay-Tolerant Dissemination: This quality attribute of a BSSAs recommends to cache ESM in frequent partitioning scenarios and disseminate them later when new vehicles are available in the ROB. Otherwise important ESM can be lost when the network in the ROB is not fully connected.

Reach ability: It is defined as the number of vehicles that could be reached by the ESM when flooding is used. It is measured by the metric called Reception Rate (RR).

- RR – The ratio between the number of vehicles that actually received the message and that could receive it if flooding is used.
-

Reliability: It defines the ability of the ESM to be delivered in despite of some link failure. It is measured by the metric called Packet Delivery Ratio (PDR). Repetition of ESM is needed to improve reliability.

- PDR – It is defined as the ratio of the vehicles in the network that have successfully received the message.
-

Channel Fading: This qualitative attribute is measured by the probability of ESM possessing error.

Every broadcast suppression algorithm should possess the above explained abilities in order to control BSP efficiently [38] .Table 1 shows the qualitative analysis of broadcast suppression algorithms to fulfill the requirements of broadcasting techniques.

The following section details the qualitative analysis of PSA, TSA and LSA.

4.2 Qualitative Analysis of PSA, TSA and LSA

Based upon the qualitative attributes explained in previous section, the reviewed BSSAs are analyzed and the results are as follows:

Table 1. Qualitative Analysis of broadcast suppression techniques to achieve the broadcasting requirements

Metrics	**Probability based algorithms**	**Timer based algorithms**	**Area based algorithms**
Scalability (Overhead, forward Ratio, broadcast Overhead)	Maximizes the broadcast overhead at the border of the broadcast range.	Minimize the forward ratio in empty slots.	Maximizes the overhead in high density network.
Robustness (Packet Loss Rate)	Maximizes the packet loss rate in the disconnected network.	Robustness is not within the scope of these algorithms	Maximizes the packet loss at low density network.
Effectiveness (Packet Received Rate)	Maximizes the broadcast packet received rate at the border of the broadcast range.	Packet received rate increased in medium density network	Minimizes the Received rate in high density area.
Dissemination Delay(E2E delay& Latency)	Dissemination delay is not within the scope of these algorithms.	Maximizes the waiting time in empty slot.	High vehicle density maximizes end to end connectivity.
Reach ability (Reception Rate)	The border nodes increases the reception rate	Not within the scope	Reception rate is increased by selecting an appropriate area of interest.
Reliability (Packet Delivery Ratio)	Not within the scope	PDR is improved by assigning equal number of vehicles distribution in each slot.	PDR is improved by receiving an ACK.
Channel Fading and shadowing (Packet Error Probability)	Not within the scope	Not considered about this problem	Not within the scope
Total Performance	Does not consider about E2E delay, reliability of the message and channel fading and shadowing.	Does not consider about robustness and reachability issues.	Does not consider about channel fading and E2E delay.

5. CONCLUSION

This paper presents an exhaustive survey of all the existing BSSA to solve Broadcast Storm Problem in VANET. The aim of this paper is to list out the functioning and limitations of the existing Broadcast Storm Suppression Algorithms which will help in proposing a new storm suppression algorithm that alleviates the existing problems. Several categories of algorithms were discussed in depth and especially three major categories of broadcasting algorithms have been chosen, namely the location, timer and probabilistic based schemes to solve BSP.

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