PBeiD Priority-based Information Dissemination Protocol for V2V Communication

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PBeiD Priority-based Information Dissemination Protocol for V2V Communication

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Abstract: In Vehicular Ad-hoc Networks (VANET)s, efficient information dissemination plays a vital role in its successful deployment. Broadcasting has proven as one of the better ways for Information Dissemination over vehicular Networks, and cooperative behaviour among vehicles for information exchange is critical. However, the existing broadcast techniques are still suffering from multiple issues such as Broadcast storm problem, network partition problem, and network contention. Motivated from the aforementioned discussion, in this paper, we propose a Priority-based Efficient Information Dissemination Protocol (PBeiD) to improve the broadcast efficiency in VANETs. PBeiD protocol developed with a blend of probability and density-based information dissemination concepts and implemented in the testbed environment using simulation tools consisting of SUMO, OMNET++, and VEINS. The proposed protocol is compared with benchmark protocols, and the simulation is carried out based on different scenarios from sparse to dense. We found that our protocol is performing well in almost all the cases and to provide proper justification that our results are significant and not by chance, we applied statistical t-test on the results obtained.

1. Introduction

The Vehicular Ad-Hoc Networks (VANETs) are the self-organizing networks, and the vehicles act as nodes to exchange useful information [1]. VANET has evolved from Mobile Ad-Hoc Network (MANET) but differs mainly due to the high mobility of nodes [2]. VANETs have the capability to cater to various services towards vehicles such as assisting in blind crossing, route computation in real-time, avoiding intersection collision, passing red lights without stopping, managing speed at curves, detection of traffic signal violation, providing multimedia services, dissemination of safety or emergency messages, assisting in highway merging, etc. To cater the different applications needs the vehicular communication utilizes two ways of communication mechanism, i.e. Vehicle to Vehicle(V2V) and Vehicle to Infrastructure(V2I)[3].V2V focus only on communication between the vehicles and forming the Ad-hoc network on the go. While V2I rely on infrastructure to communicate with vehicles. The Vehicle to Vehicle (V2V) communication also known as cooperative communication [4]. To enable cooperative communication, a Dedicated Short-Range Communication (DSRC) spectrum of 75 MHz (5.85 to 5.925 GHz) is allotted by the U.S. Federal Communication Commission[1]. The spectrum contains seven channels of 10Mhz wide each and have 1 Control Channel (CCH) and 6 Service Channel (SCH). To create a cooperative awareness among all nodes in the network small periodic packets are exchanged, and the process is known as beaconing, these packets contain necessary information such as speed, position, and direction of a vehicle. The beaconing process is always done on CCH while non-critical messages are transferred through SCH. The IEEE 802.11p also specifies the Medium Access Control (MAC) protocol for single-channel operation [5].

The information dissemination in V2V happens through single-hop, and multi-hop broadcasting mechanisms. In single-hop broadcasting, vehicle periodically sends the information packets to its one-hop neighbourhood. On the other hand, in multi-hop broadcasting the vehicle sends its onboard information using flooding mechanism, flooding mechanism broadcasts the packet to all the vehicles in transmission range[6]. To cover the extensive range of communication, multihop broadcasting is always preferred in

VANETs. However, multihop broadcasting suffers from two major issues, i.e. the broadcast storm problem [7] and the network disconnection [8] problem.

1.1 Motivation

- The existing Information dissemination algorithms on VANET are not that matured enough to meet its vision [42], [43], [44].
- Any generated information must be quickly distributed among nodes [45].
- Moreover, there is no intelligent mechanism to prioritize the crucial type of information, which must be disseminated without any delay.

1.2 Research Contributions

The present research work is focused on "Efficient Information Dissemination in Vehicular Ad-hoc Networks using intelligent Multicast" and the contributions are:

a) Priority-based Information Dissemination in VANETs (PBeiD) comprising of:
   a. Message prioritization algorithm.
   b. Density of nodes algorithm.
   c. Rebroadcast probability algorithm.
   d. Rebroadcasting Algorithm.

b) Exhaustive Graphical comparison of results.

c) Exhaustive Statistical comparison of results.

1.3 Organization

The rest of the paper is structures as follows: Related work is presented in Section **Error! Reference source not found.**; Section 3 presents the proposed protocol Priority-based efficient Information Dissemination (PBeiD) followed by the details of a microscopic traffic simulation model, evaluation of proposed protocol and statistical analysis in Section **Error! Reference source not found.** and finally section 5 concludes the paper with future work discussion.

2. State of the Art

Broadcasting is the more suitable and reliable information dissemination technique for vehicular communication. Figure 1 presents the taxonomy of broadcasting protocol for information dissemination over VANETs. This taxonomy is divided into 2 categories i.e., Single hop and multi-hop broadcasting.

- In single hop broadcasting, the information is disseminated to immediate neighbours only.
- In Multi-hop broadcasting the information is disseminated via repeated flooding to all possible neighbours.

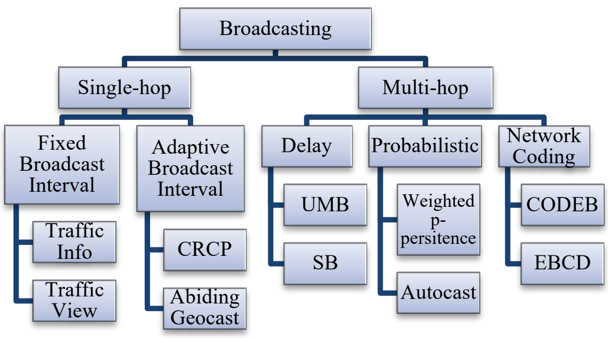

Figure 1. Classification of popular Information Dissemination protocol

1.1 Single-hop Broadcasting Protocols

The single-hop protocols broadcast the updated information to the vehicles in one hop transmission range. Single hop broadcasting protocols rely primarily on the mobility of the vehicle; high mobility of vehicle would spread the information to farthest node. The two key parameters of the single-hop broadcasting protocol are as follows:

1) information to be broadcasted, and
2) the selection of broadcast interval.

Broadcast interval value setup is crucial, and it improves efficiency of the protocol. Broadcast interval with high values would miss the relevant information, and low value would cause the redundant packet over the network and packet collision. There are two popular ways to set up the interval value, i.e., Fixed broadcast and Adaptive broadcast interval, which are explained as follows.

1.3.1 Fixed Broadcast Interval

This category of single-hop broadcasting protocol focuses on selecting and aggregating critical broadcasting data. The packet receiving vehicle process the received packets and synchronizes its stored database, selection and aggregation procedures updates the packets with the changed information in order to broadcast in the next broadcast cycle.

The author in [9] proposed TrafficInfo algorithm, in this single hop fixed broadcast interval algorithm, each vehicle periodically broadcasts information from the onboard database. Broadcasting in TrafficInfo is done by assuming that every vehicle is equipped with digital road map of the road segments it travels, and every vehicle has equipped a Global Positioning System (GPS). The digital map contains various road segments, with each having a unique identification number. Vehicles would exchange the onboard database information among themselves. The onboard database contains the information of the current road segment, speed of vehicle with timestamp. This protocol uses a ranking algorithm to rank the information, the first n records from the ranked information get selected for broadcasting. The ranking algorithm primarily depends on the current location of the vehicle on a road segment and current time. The information is ranked such that information related to closer road segments are given priority as compared to the farther ones.

The author in [10] proposed the TrafficView framework to disseminate and gather information about the vehicle on the road; it broadcasts information based on results of the ratio-based algorithm and cost-based algorithms. In this framework, vehicles store the received packets in its onboard database and share the information related to speed and position in broadcast cycles.The simulation results of TrafficView, with the ratio-based algorithm, gives greater flexibility and with the cost-based algorithm yields greater accuracy.

1.3.2 Adaptive Broadcast Interval

The adaptive broadcast interval considers the broadcast interval in addition to the selection and aggregation of the critical information.The author in [11] proposed a Collision Ratio Control Protocol(CRCP), CRCP is a single-hop broadcasting protocol, and it broadcasts information periodically, and this information includes speed, location and the roadID. This protocol is adaptive to the network density and controls the number of packet collisions by adjusting the broadcast interval value in the network. This protocol follows the following mechanism to set the broadcast interval value. This protocol comprises the following methods to select the information for broadcasting, i.e., Vicinity Priority Selection (VPS), Vicinity Priority Selection with Queries (VPSQ), and Random Selection(RS).

- *Vicinity Priority Selection (VPS):* This method gives priority to the information related to the nearby road segments.
- *Vicinity Priority Selection with Queries (VPSQ):* VPSQ is an enhanced version of VPS where it lets the vehicle for querying the information of a road segment instead of only receiving the information passively.
- *Random Selection (RS):* with this method, the vehicle randomly chooses the records from its onboard database for the next broadcast.

The authors in [12] proposed the Abiding Geocast protocol, and this protocol enables the dissemination of safety information to the geographically required areas. The packet generated on emergency events contains the coordinates of the area of importance, and the receiving vehicle continues to broadcast it to till the required area. On information dissemination to the required area, this protocol drops the packet and stop its broadcasting. This protocol adjusts its retransmission interval dynamically to minimize the amount of packet collisions. The retransmission interval depends on various factors such as speed, range of transmission, and vehicle distance to the emergency site.

1.2 Multi-hop Broadcasting Protocols

This category of protocols spread the information via flooding. In flooding the source vehicle sends the packet to other vehicles in the vicinity, and later, the vehicles that received the information would flood over the network in the next broadcast cycle. Similarly, broadcasts happen over and over, and the packet reaches to the faraway vehicles. However, pure flooding has scalability and packet collision issues, and in case of dense network, these issues are much severe. To address these issues, various researchers have proposed improvements over multihop broadcasting protocols, which are described as follows.

1.2.1 Delay-Based Multi-Hop Broadcasting

In this approach, a delay is assigned to vehicle nodes before they rebroadcast the packet and the vehicles with minimum waiting delay, i.e., the function of the distance between transmitter and vehicle, gets a higher priority and is allowed to rebroadcast the packet. Once the packet rebroadcasts, other vehicle stops rebroadcasting of the same packet. Thus, in order to maximize the packet forwarding, the farthest vehicle is assigned the shortest delay, by providing it with the highest priority to rebroadcast the packet. The various protocols proposed in the literature for delay-based multi-hop broadcasting are discussed as follows.

The author in [13] proposed Urban Multi-Hop Broadcast(UMB) protocol, in UMB, the vehicle divides the area under its transmission range into smaller segments, and it assigns the highest priority to the vehicle in the farthest segment. The packet forwarding in UMB are of two types, i.e., directional and intersectional broadcast. In the directional broadcast, a vehicle divides the road into segments and sends a packet called Request to Broadcast (RTB) to all the vehicles in its transmission range. RTB contains the location of source vehicle and the direction of propagation of the message. Different vehicles on receiving RTB start transmitting a jamming signal called black burst, and its duration will be calculated as follows:

$$B = \left(\frac{s}{T} \times N\right) \times S \qquad (1)$$

Where B is the black burst duration, s is the distance between receiver and source, T is the transmission range of the source, S is time slot duration, and N is a maximum number of road segments.

All the vehicles emit the jamming signal as per their black burst duration and start sensing the channel. If the channel is idle, the vehicle starts rebroadcasting the packet else it aborts its rebroadcasting process. This way the farthest vehicle from the source, gets the highest black burst duration and it becomes the next rebroadcast vehicle, and thus it sends Clear to Broadcast (CTB) packet back to its source. After receiving CTB, source starts transmitting the packet (DATA) and the next broadcast vehicle sends an ACK back on receiving the packet. In case of a collision, the whole process of RTB-CTB-DATA-ACK starts over again. The second type of transmission in UMB is intersectional transmission, and it deals with retransmission using infrastructure at road intersections. UMB was designed to address broadcast storm and hidden node problems.

UMB has a limitation due to its long black burst durations to overcome the UMB limitation the author in [14] proposed Smart Broadcast (SB) . Smart Broadcast designates the node having the shortest waiting delay as the next rebroadcast vehicle. The source vehicle sends the RTB packet to all the vehicles in its transmission range. The vehicles decide their contention delay based on the sector they are present, by using the set as follows.

$$W = \{ (s-1)\,\mathrm{cw}, (s-1)\,\mathrm{cw}+1, - - - - - - - - , s * \mathrm{cw} - 1 \} \quad (2)$$

Where s = 1,2,- - - - - N_s refers to the sector number, (s=1 being the outermost, and *cw* refers to the contention window size. Using this set, the vehicle in the outermost sector gets the minimum delay and thus becomes the next rebroadcast vehicle. Vehicles residing in the same sector chose their waiting times randomly. This mechanism helps to reduce packet collision rate and address the latency issue as well.

1.2.2 *Probabilistic-based Multi-Hop Broadcasting*

In the probabilistic based multi-hop broadcasting protocol, the probability distribution function is used to assign the rebroadcast priorities. This assignment of different broadcast priorities to vehicles leads to the reduction in the number of redundant packets and the reduction of the number of packet collisions.
The author in [7] proposed Weighted p-persistence[7] technique. This technique computes the probability to rebroadcast for each vehicle and decides its broadcast priority. The following function is used to compute the probability to rebroadcast by the vehicle receiving the packet for the first time.

$$p_{ij} = \frac{D_{ij}}{R} \quad (3)$$

Where p_{ij} is the probability to be calculated, D_{ij} is the distance between the transmitter and the vehicle, and R is the transmission range of the vehicle. Based on the value calculated for p_{ij} the farthest vehicles get the highest probability to rebroadcast. The major drawback of this protocol is not considering network density into an account. In a dense network, this protocol may result in an increased number of packet collisions due to the supply of redundant packets.

The author in [15] proposed the AutoCast protocol. In this protocol, the forwarding probability is calculated using a function dependent on the number of neighbours in the vicinity of that vehicle. This protocol accounts for the density of the network; that is, it changes the forwarding probability according to the density of the network. The following function is used to calculate the forwarding probability:

$$p = \frac{2}{N_h \times 0.4} \quad (4)$$

Where p is the forwarding probability and N_h is the total number of neighbours that are reachable in one hop. The protocol has a limitation that the function cannot work when the number of vehicles in a transmission range is less than 5. However, the protocol provides a mechanism to enhance reachability by adjusting the rebroadcast interval of using the following function.

$$t = \frac{N_h}{\alpha} \quad (5)$$

Where t is the rebroadcast interval, N_h corresponds to the number of vehicles in the vicinity of the transmitter and α is a constant. This protocol considers the network density and dynamically sets the broadcast interval value; this mechanism helps in reduction of packet collision and increase the packet delivery ratio.

1.2.2 Network coding based Multi-Hop Broadcasting

The networking coding-based approach reduces the total number of transmissions and thus, increases the throughput of the system, resulting in utilizing the bandwidth to make the network more efficient. The Network coding-based protocols were designed for mobile ad-hoc networks, and not much of the research had been done on them to be applied in the field of VANETs. Some of the protocols have been designed for VANETs are discussed here:

The author in [16] proposed CODEB, and the CODEB is an extension of the COPE[17] protocol. It relies on opportunistic learning, where it overhears any packet that it can. Apart from opportunistic learning, each node broadcasts the list of all its one-hop neighbours. This list facilitates the generation of a graph of each node with its two-hop neighbours. This graph is useful in generating a broadcasting backbone and is further used to broadcast efficiently. The CODEB uses opportunistic coding to determine whether a node can handle encoded packets or not while the COPE uses unicast routing. The opportunistic coding is more natural as it sends the encoded packet to one node only and therefore has to make sure that only that particular node can handle the encoded packet. Whereas the CODEB performs the broadcasting, and thus it has to ensure that all its neighbours can process the encoded information. This process adds another layer of complexity in the functioning of this protocol. CODEB then deterministically chooses a set of neighbours to forward the packet, contrary to probabilistic broadcasting where a set is randomly selected to broadcast. All nodes use the Partial Dominant Pruning algorithm to generate a forwarder list. This list contains all the nodes so that all of its two-hop neighbours are covered. The packet can only be transmitted by the nodes in the forwarder list. In cases where all the two-hop neighbours of a node have already received the data packets, the rest of the nodes in the forwarder list halt their broadcast process. By using network encoding, CODEB outperforms other protocols in terms of both the packet delivery ratio and the complete number of transmissions or broadcasts required to deliver a packet to all the nodes participating in the network.

The author in [18] proposed the Efficient Broadcasting using Network Coding and Directional Antennas (EBCD) protocol, combining the features of network coding with that of directional antennas. This network coding-based protocol works similar to CODEB as it also finds a set of forwarder list deterministically. This list contains a set of nodes to be used to broadcast the packet in order to make sure that all nodes in the network receive the packet. However, it uses a algorithm unlike CODEB called as Dynamic Directional Connected Dominating Set (DDCDS). This algorithm generates a backbone of a directional virtual network where each node determines its forwarding status and all outgoing edges where a packet is sent. EBCD applies network coding in each of the outgoing edges or sectors of the directional antennas. Simulation results show that EBCD performs better in terms of a total number of transmissions as compared to protocols using only network coding or the ones using none of these.

3. PBeiD: The Proposed Protocol

This section explains the proposed protocol for efficient information dissemination over VANET which maximizes the radio channel utilization and message transmission to maximum nodes in minimum time. Network density and message priority are the significant factors which influence the information dissemination. Various research studies have focused on message classification to prioritize crucial information for effective dissemination, and this approach has given encouraging results[19][20]. This protocol works in three stages, at first stage the message will be generated and prioritized along with direction, at second stage message will be received by nodes in the vicinity, and every receiving node will compute density, delay, and probability to rebroadcast and finally, at the third stage the algorithm decides to broadcast the message or not. This protocol is fully compatible with IEEE 802.11p standards[21].

3.1. Message Prioritization

In general, the broadcast mechanism spread the information circularly without any direction specific. However, in real-world scenarios, specifying the direction to messages would improve the dissemination efficiency, e.g. Ambulance information needs to be propagated to forward vehicle and sudden brake information required by the following vehicles. Based on this logic, in this step messages are classified by propagation direction along with its priority. Messages are classified into five classes, and each class adopts a specific broadcast policy. The following Table 1 presents the priority and direction with example and Fig. 2, Fig. 3 and Fig. 4 depicts the scenario for all classes.

Table 1: Class of Message based on Priority and Direction

Class	Priority	Direction	Example
1	High	Backward	Accident, Sudden Brake, Bad Road
2	High	Forward	Ambulance, Fire Vehicle
3	Medium	Backward	Traffic Updates, Infotainment
4	Medium	Forward	Other Infotainment
5	Low	Both	General Broadcast

Class 1 message indicates an emergency message backward direction dissemination, e.g., Accident, Sudden Brake detection, etc. These messages are of zero tolerance and should be disseminated as early as possible to all the following vehicles.

Class 2 message indicates an emergency vehicle trying to overtake vehicles in front, and this message needs to be disseminated in the forward direction, e.g., Ambulance, Fire Vehicle, etc. These messages are also of high priority and should be disseminated as early as possible to all ahead vehicles.

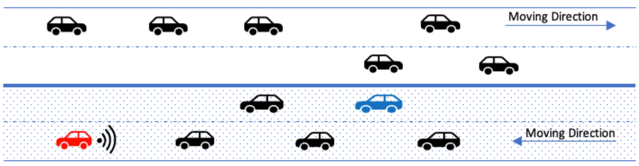

Fig. 2. Class 1 & Class 3 Message, Backward Broadcast

Class 3 message indicates message with medium priority and backward direction dissemination, e.g., Traffic Updates, Infotainment Applications. These messages are of medium priority and possess less critical information.

Class 4 message indicates message with medium priority and forwards direction dissemination, e.g. Traffic Updates, Infotainment Applications. These messages are of medium priority and possess less critical information. The primary purpose is to share traffic information among nodes and finally updating this information to traffic monitoring applications.

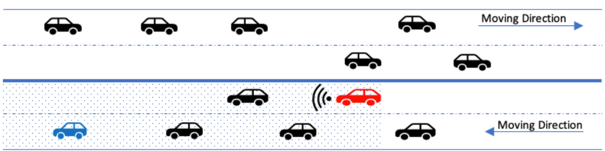

Fig. 3. Class 2 & 4 Message, Forward Broadcast

Class 5 message indicates a general message, e.g., point of interest, advertisement service, weather information, etc. These messages are of low priority and can be disseminated separately (with permissible latency), Fig. 4 depicts the scenario. Our protocol makes use of V2I approach to disseminate such kind of messages. Broadcast policy this class of messages has already been proposed in our work[22].

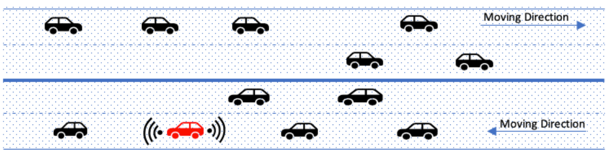

Fig. 4. Class 5 Message, General Broadcast

3.2. Density of Nodes

Network density plays a vital role in setting up the rebroadcast parameter value. In real-world scenarios, network density is dynamic. In, this section a novel network density computation method is proposed, this network density computation function is adaptable to changing network scenarios. The proposed method uses beaconing[23], with the help of beaconing each node maintains list of its two-hop neighbours' information such as speed, distance, and coordinates. The list is pruned based on distance threshold of communication range. The following function computes the density.

$$density = \frac{\alpha * h_0 + (1 - \alpha) * h_1}{2} \tag{6}$$

where h_0 is the one-hop neighbours, h_1 are two-hop neighbours and α is a density constant and is between $0<\alpha<1$. The value of α is chosen based on the following table.

Table 2: **Value of Alpha**

Value of α	Deciding factor	indicator
Towards 0	$h_0 < h_1$	Sparse network
Towards 1	$h_0 > h_1$	Dense network
No effect	$h_0 = h_1$	Moderate network

Rebroadcasting Probability (P_{rb}): rebroadcasting probability indicates the rebroadcast probability of a packet. To determine P_{rb} value of a packet, multiple experiments have been carried out and found 0.3 as the threshold value, and the packets with above 0.3 P_{rb} are fit for rebroadcasting. The P_{rb} is calculated using the equation (7) where density is calculated from equation (6), and Nodes are the number of vehicles in the network.

$$P_{rb} = 1 - \frac{density}{Nodes} \tag{7}$$

Delay between Rebroadcast (*D_{rb}*): The delay between rebroadcast is the waiting time before rebroadcasting the packet; this value needs to be set such that farthest node should rebroadcast as early as possible. So, we calculate this delay using the range of communication medium, distance to the initiator, and Probability to rebroadcast. The D_{rb} is calculated using equation (8).

$$delay(D_{rb}) = \left(\frac{Range - distance}{Range * Prb}\right) milliseconds \tag{8}$$

Number of Rebroadcast (*N_{rb}*): This parameter is used to ensure a failsafe system, as broadcasting does not have an acknowledgment mechanism. So, if the packet is received many times, then a delay of 1ms is added to the previously scheduled message, and the value of N_{rb} is decremented by 1. This delay ensures the packet to broadcast at least once and if anytime during the scheduled phase the N_{rb} value becomes 0 or negative all scheduled broadcast message are cancelled.

MaxDistance to broadcast (*M_{db}*): The Maximum distance to rebroadcast defines the area of coverage, if the packet has reached this value then no further dissemination is done. This work considers the value of M_{db} to be maximum.

3.3. Working of the Protocol

The overall protocol contains four procedures which are explained below, and the flow chart of the received packet is depicted in Figure 5.

Generate Packet: Source node generates the new packets of information along with the additional information such as priority, direction, class and farthest neighbour. Generated packets will be broadcasted, and receiving vehicles handles the packets. The following Algorithm 1 presents the generate warning packet procedure.

ALGORITHM 1: GENERATE WARNING PACKET

PROCEDURE GENERATEWARNING PACKET
Farthest Neighbor (Fn) ← GetFarthestNeighbour
Class (CID) ← AssignClassID
MaxDistance (M_{db}) ← Max Distance to Broadcast
AddFarthestNeighbourAndClassAndMaxDistance (Fn, CID, M_{db})
Broadcast(P)

Receive Packet: Receiving node executes the proposed received packet procedure. The proposed receive packet procedure identifies the suitable packets to rebroadcast and pass them to rebroadcast procedure along with its delay to rebroadcast. The algorithm 2 gives pseudocode for received packet procedure. In this procedure, initially packets that have already covered desired area would be rejected, packets that have not covered the desired area will be passed to check direction procedure described in Algorithm 4. Based on the direction of the sender and receiver check direction procedure flags the nodes to participate further or not. The nodes that are flagged to rebroadcast calculates the network density and probability to rebroadcast (P_{rb}) using equation (7) and (8) respectively. The calculated P_{rb} value is greater than 0.3, then the message will be scheduled to rebroadcast with the calculated delay as mentioned in the pseudocode.

ALGORITHM 2: RECEIVE PACKET

procedure RECEIVE PACKET(P)
if P has not covered the desired area **OR** P do not belong to Class 5 then
    If Checkdirection(P)
        If P is received for the first time, then
            Calculate density using → $density = \frac{\alpha * h_0 + (1-\alpha) * h_1}{2}$
            Calculate Probability to Rebroadcst → $P_{rb} = 1 - \frac{density}{Nodes}$
            If $P_{rb} > 0.3$ then
                RebroadcastFlag ← *true*
                If myDistancetoSource > farthest (Fn)
                    delay = 0 milliseconds
                Calculate delay using → $delay(D_{rb}) = \left(\frac{Range - distance}{Range * Pr}\right)$ *milliseconds*
                ScheduletoReBroadcast (delay, P, Rebroadcast)
            else
                RebroadcastFlag ← *false*
        else
        N_{rb} of previously received packet = N_{rb} -1
        SchdeuletoReBroadcast (1, P, Rebroadcast)
    else
        RebroadcastFlag ← *false*
else

20: End the Algorithm

Rebroadcast: All the rebroadcast are scheduled by receive packet procedure and also the value of N_{rb}. This procedure checks for rebroadcast flag and value of N_{rb} before rebroadcasting. If the rebroadcast flag is false or N_{rb} value is zero or negative, it cancels the rebroadcast. Otherwise, it checks for class and broadcast the packet on CCH/SCH accordingly. In case of class 1 and 2 it also adapts store carry forward approach so that message is disseminated even in the case of hidden node problem.

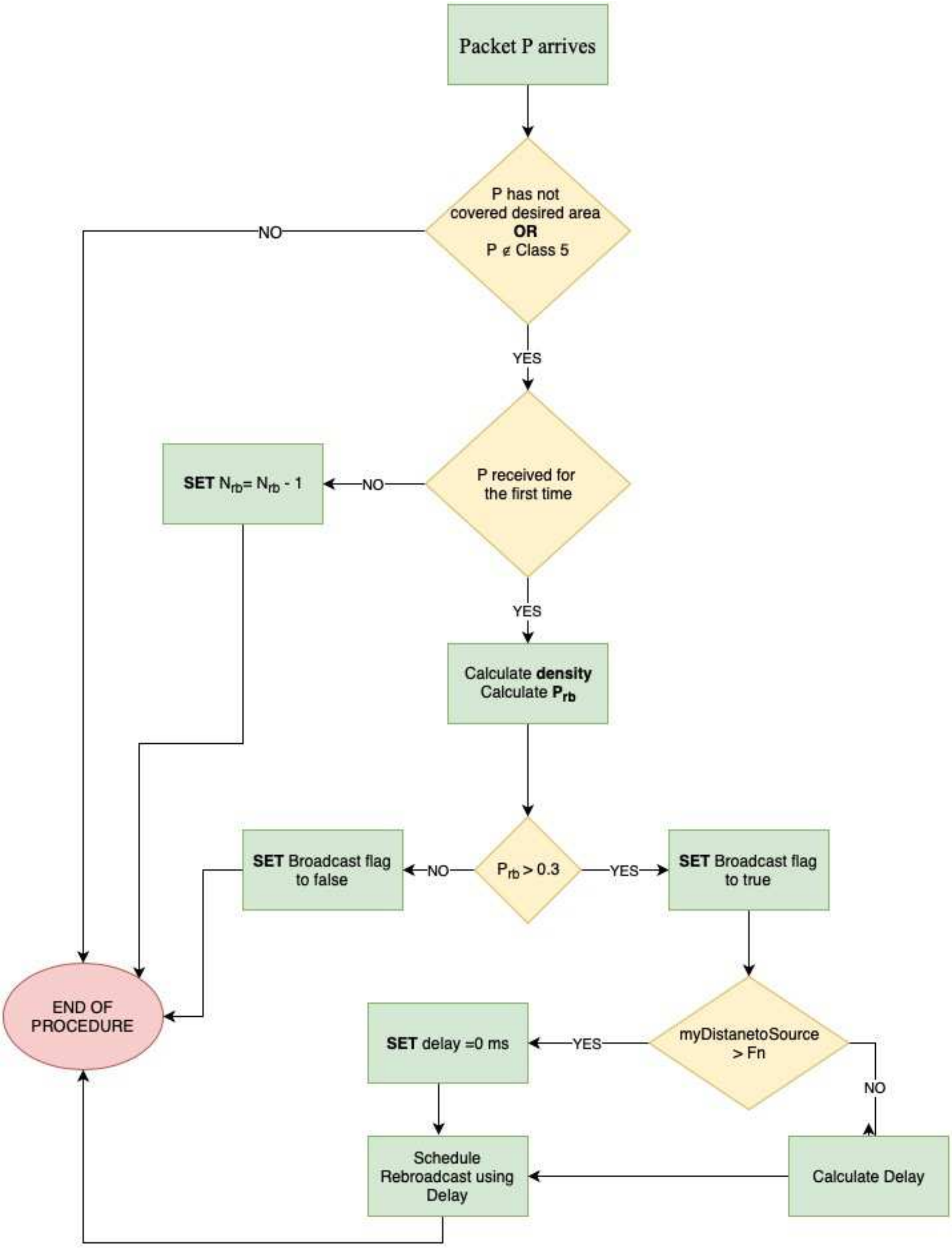

Fig. 5. Flowchart of Receive Packet in PBeiD

ALGORITHM 3: REBROADCAST

```
procedure REBROADCAST(P)
  if RebroadcastFlag is true, then
     If N_rb is not less than or equal to 0
        If P belongs to class 1 OR class 2 then
           Broadcast(P) using CCH
           Store Carry and Rebroadcast after delay
        else if belongs to class 3 OR 4 then
           Broadcast(P) using CCH or SCH
     Else
        cancelRebroadcast
  else
     End the Algorithm
```

ALGORITHM 4: CHECK DIRECTION

```
procedure CHECKDIRECTION(P)
  GET Sender position from P
  GET Receiver Position
  Direction ← Calculate angular direction of sender and receiver
  if CID is "1" and Direction is positive
          Return true
  else if CID is "2" and Direction is negative
          Return true
  else if CID is "3" and Direction is positive
          Return true
  else if CID is "4" and Direction is negative
          Return true
  else
          Return false
  End of Algorithm
```

4. Performance Evaluation

To evaluate PBeiD protocol performance, we carried out set of simulation-based experiments, and compared with the benchmark protocols such as Flooding based [24], Probabilistic based [25], [26], distance-based [27] and counter-based [28].

4.1. Simulation setup and parameters used

The Simulation is carried out in OMNET++[29] and VEINS[30] framework. The mobility scenario extracted from OpenStreetMap[31], the city environment of 5 x 5 km. Further to make the mobility scenario as more realistic a curved road segment which merges into a two-lane highway has also been considered. This scenario helps to observe the effect of signal loss in DSRC[32]. The simulation parameters are described in Table 3. The mobility model is generated for variable vehicles running on a curved road with random speed. An accident message is introduced in the network at time when all vehicles are in network during the simulation. The objective is to encompass maximum real-world conditions during the simulation. The simulation is executed for a total of 450 for 30-110 nodes and 475 seconds for 130-150 nodes. The mobility model and the network parameters are kept constant for all the five-algorithm implementation.

Table 3 : Simulation Parameters

Parameter	Value
Field	City: 5000m x 5000m,
Simulation Duration	450s/475s
Scheduled Accident	Random time on mid of n/w
Transmission Range	300m
Beaconing Interval	3s
Mobility	Fixed path
Vehicle Speed	Random with (acceleration = 2.6 m/s,maxSpeed=14 m/s)
Average Speed	13.41 m/s
Number of Nodes	30,50,70,90,110,130,150
Data Packet size	512 byte
MAC protocol	IEEE 802.11p

4.2. Performance metrics and evaluation

The performance of PBeiD is evaluated based on the following metrics [33]

Propagation Time: The propagation time is defined as the difference of time between the packet generation at the source node and reception of first message at the last node. Minimizing this value makes an algorithm efficient.
Reachability Ratio: The Reachability Ratio is defined as the ratio between reachability and propagation time.
Number of Retransmission: The number of packets generated on all nodes during the retransmission of the packet. Generating a higher number of rebroadcasts creates network contention and broadcast storm problem. This parameter should be minimized to make a congestion-free network.
Total packet Loss: The number of collisions is dependent on the total number of retransmissions done if higher retransmission is done then higher packet would generate in the network and there are chances of getting more packet collision. This will affect overall performance of network.

4.2.1. Evaluating the Propagation time of PBeiD

The propagation time is the time taken by a message to be delivered to the last accessible node in the network. Figure 6 shows the performance of PBeiD protocol against different techniques in sparse to dense network environment. The propagation time is calculated using equation (9). We can observe that PBeiD protocol is consistently performing well in almost all the scenarios. Only the distance-based approach is outperforming the PBeiD protocol with very little difference.

$$PT = ReceiveMsgTime - InitTime \quad (9)$$

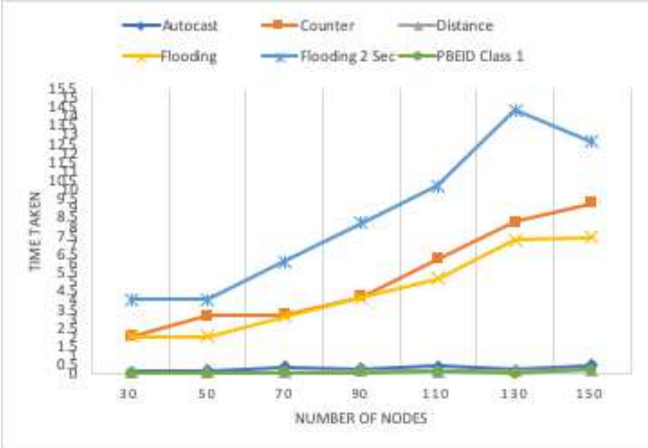

Figure 6: Number of Nodes vs Propagation in Time Class 1 Messages

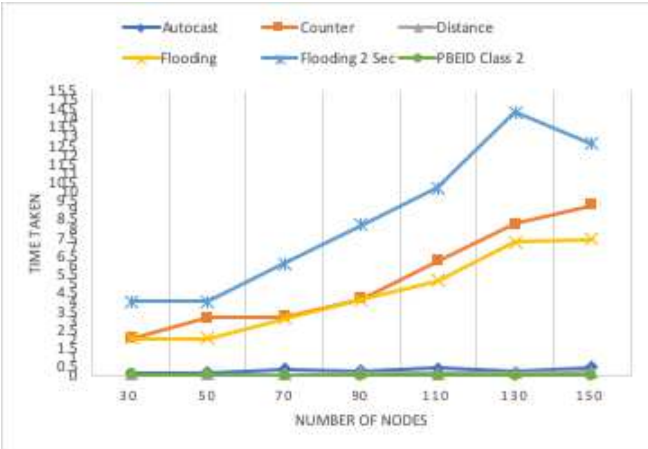

Figure 7: Number of Nodes vs Propagation in Time Class 2 Messages

4.2.2. Evaluating the Reachability Ratio of PBeiD

The reachability refers to the overall coverage of the message, and it is always expected that message covers the entire network for which it was intended. The reachability is affected by many parameters such as collision, blind node, network contention, etc. The Reachability is calculated using equation (10).

$$\text{Reachablity}= \frac{\text{NumberVehicleReceived}}{TotalVehiclesinNetwork}*100 \qquad (10)$$

The reachability value calculated using Eq.(10) provides the percentage of the intended vehicle receives the message. Furthermore, the ratio between the Reachability in Eq.(10) and the PT calculated in Eq.(9) provides the Reachability ratio which also considers the reachability in the time taken. The Reachability Ratio is calculated using the following equation

$$\text{Reachability Ratio}= \frac{\text{Reachability}}{PT} \qquad (11)$$

In the following figure, we can see that PBeiD is performing best in contrast to all other algorithms.

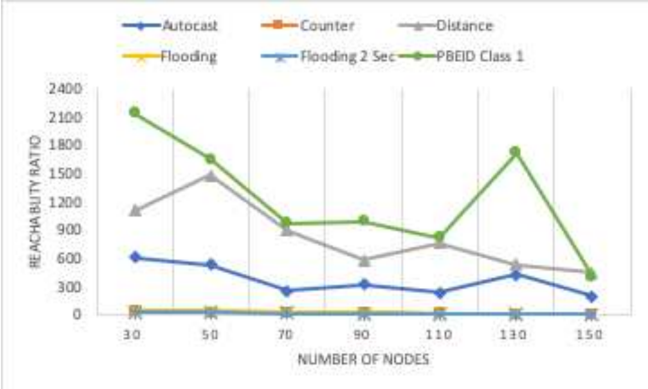

Figure 8: Number of Nodes vs Reachability Ratio Class 1 Messages

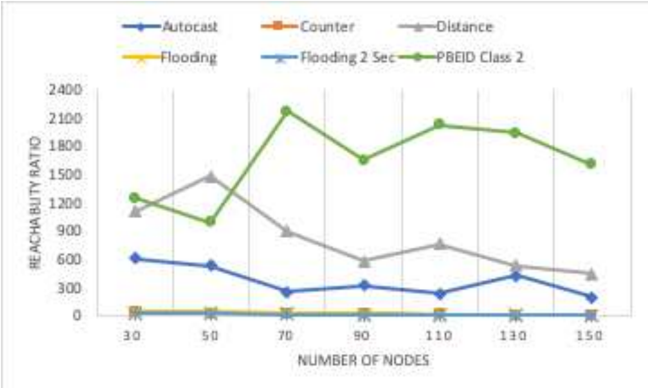

Figure 9: Number of Nodes vs Reachability Ratio Class 2 Messages

4.2.3. Evaluating the Number of Retransmissions of PBeiD

The number of retransmissions is the total number of packets generated on all the nodes in the network. These packets are generated when a node decides to retransmit the incoming packet. If all the receiving nodes are retransmitting the message, then it may result in network contention and collision. The number of retransmissions is calculated using equation (11)

$$NoOfRetransmission = \sum_{x=1}^{TotalVehicles} PacketGeneratedat(x) \tag{11}$$

In Figure 10, we can see that flooding and distance-based techniques are gradually increasing packet generation as the number of nodes are increasing. On the other side, we could see that PBeiD is performing very well here and it is generating the minimum number of packets. We can also observe that due to the adaptive parameters packet generation is decreasing as number of nodes are increasing.

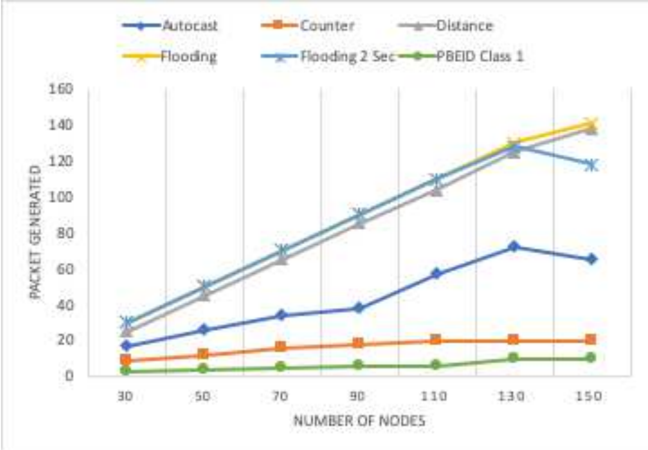

Figure 10: Number of Nodes vs Packet Generated in Class 1

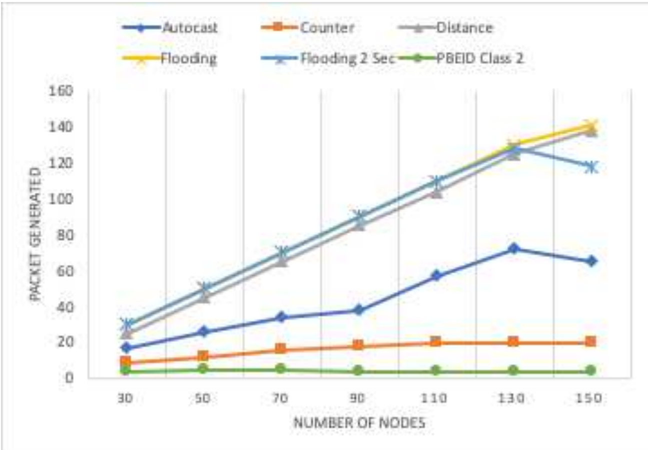

Figure 11: Number of Nodes vs Packet Generated in Class 2

4.2.4. Evaluating the Total Packet Loss of PBeiD

The number of collisions refers to the number of packets lost in receiving and transmission at physical layer due to uncontrolled random circumstances like obstacles, buildings, signal fading, etc. this also includes the packet collision occurred due to network contention. The total packet loss is calculated using equation (13).

$$TotalPacketLoss = \sum_{x=1}^{TotalVehicles} RxLost(x) + TxLost(x) + SNIR_{lostpackets} \tag{13}$$

However, these values are generated due to the random behaviour of our simulator every time; still, we can observe in Figure 12 that PBeiD is performing well.

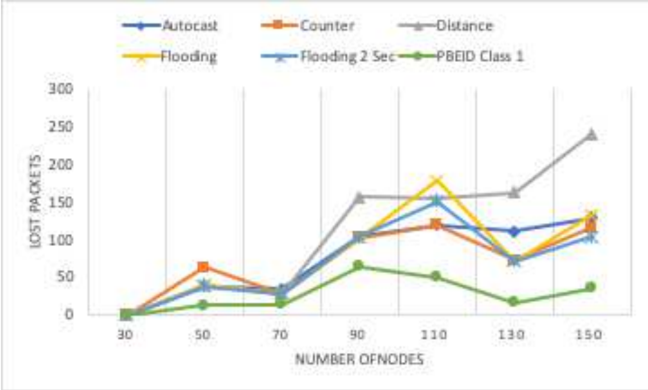

Figure 12: Number of Nodes vs Rx Tx Lost Packets Class 1 Messages

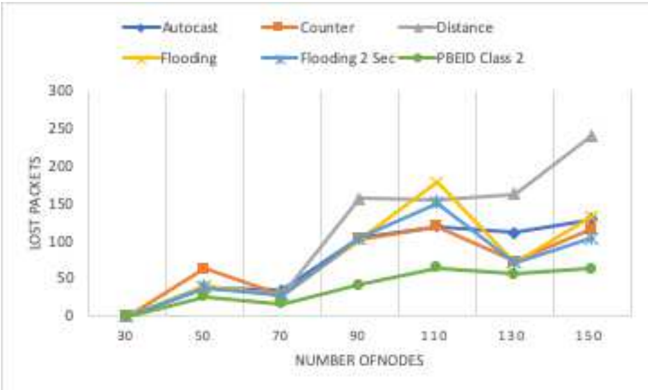

Figure 13: Number of Nodes vs Rx Tx Lost Packets Class 2 Messages

4.3. Statistical Analysis

The empirical values and graphical representations have established the PBeiD performance. Further, we carried out the statistical analysis over the obtained simulation results to establish the result authentication. We have carried out two-tailed, two-sample equal variance (homoscedastic) t-test and the following subsection presents the t-test results analysis of all four parameters studied respectively.

4.3.1. Propagation Time

4.3.1.1. Statistical Analysis for Class 1 Messages

The following table presents the detailed result and analysis for two independent samples, a lower tailed t-test with a significance level of 5% w.r.t. the propagation time of PBeiD class 1 messages along with compared protocols. An optimal algorithm requires minimum propagation time, we tested our results and found PBeiD class 1 as significant in all other cases than the distance-based algorithm.

Table 4: Statistical Analysis for Class 1 Messages w.r.t. Propagation Time

Propagation Time						
# Node/Technique	Autocast	Counter	Distance	Flooding 1 Sec	Flooding 2 Sec	PBEID Class 1
30	0.16335454	2.03984114	0.090524	2.03983173	4.03741914	0.046633
50	0.188492	3.17096077	0.06740809	2.06679638	4.07368524	0.0603867
70	0.38749816	3.22017995	0.111197	3.10286586	6.11024953	0.1030382
90	0.30945716	4.20799353	0.17077356	4.1576121	8.21866051	0.100846
110	0.42254208	6.23368251	0.12979437	5.19697583	10.230658	0.121835
130	0.23360201	8.25656994	0.18724773	7.26160692	14.3158911	0.058181225
150	0.48142893	9.27413739	0.21441028	7.40822359	12.6344948	0.242679665

Research Question:	Is PBEID Class 1 (μ1) better than (μ2) concerning Propagation Time ?

μ1:	mean (Propagation Time of	PBEID Class 1)
μ2:	mean (Propagation Time of	Autocast/Counter/Distance/Flooding 1 Sec/Flooding 2Sec)

Hypothesized difference (D):	0
Significance level (%):	5
Population variances for the t-test:	Assume equality

t-test for two independent samples / Lower-tailed test:

t-test for two independent samples / Lower-tailed test: 95% confidence interval on the difference between the means							
Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
PBEID C1	7	0	7	4.66E-02	2.43E-01	1.05E-01	6.69E-02
Autocast	7	0	7	1.63E-01	4.81E-01	3.12E-01	1.23E-01
PBEID C1	7	0	7	4.66E-02	2.43E-01	1.05E-01	6.69E-02
Counter	7	0	7	2.04E+00	9.27E+00	5.20E+00	2.77E+00
PBEID C1	7	0	7	4.66E-02	2.43E-01	1.05E-01	6.69E-02
Distance	7	0	7	6.74E-02	2.14E-01	1.39E-01	5.38E-02
PBEID C1	7	0	7	4.66E-02	2.43E-01	1.05E-01	6.69E-02
Flooding 1 Sec	7	0	7	2.04E+00	7.41E+00	4.46E+00	2.26E+00
PBEID C1	7	0	7	4.66E-02	2.43E-01	1.05E-01	6.69E-02
Flooding 2 Sec	7	0	7	4.04E+00	1.43E+01	8.52E+00	4.07E+00

H0:	The difference between the means is greater or equal to 0, i.e. μ1 - μ2 >= 0.
Ha:	The difference between the means is lower than 0, i.e. μ1 - μ2 < 0
Significance Value	0.05

Research Conclusion							
PBEID C1 vs	Difference	t (Observed value)	t (Critical value)	DF	p-value (one-tailed)	Rejected Hypothesis	Research Answer
Autocast	-2.08E-01	-3.93E+00	-1.78E+00	12	9.95E-04	H0	**Significantly YES**
Counter	-5.10E+00	-4.87E+00	-1.78E+00	12	1.94E-04	H0	**Significantly YES**
Distance	-3.40E-02	-1.05E+00	-1.78E+00	12	1.58E-01	Ha	**Significantly NO**
Flooding 1 Sec	-4.36E+00	-5.10E+00	-1.78E+00	12	1.30E-04	H0	**Significantly YES**
Flooding 2 Sec	-8.41E+00	-5.47E+00	-1.78E+00	12	< 0.0001	H0	**Significantly YES**

4.3.1.2. Statistical Analysis for Class 2 Messages

The following table presents the detailed result and analysis for two independent samples, a lower tailed t-test with a significance level of 5% w.r.t. the propagation time of PBeiD class 2 messages along with compared protocols. An optimal algorithm requires minimum propagation time, we tested our results and found PBeiD class 2 as significant in all cases.

Table 5: Statistical Analysis for Class 2 Messages w.r.t. Propagation Time

Propagation Time						
# Node/Technique	Autocast	Counter	Distance	Flooding 1 Sec	Flooding 2 Sec	PBEID Class 2
30	0.16335454	2.03984114	0.090524	2.03983173	4.03741914	0.080178
50	0.188492	3.17096077	0.06740809	2.06679638	4.07368524	0.100843
70	0.38749816	3.22017995	0.111197	3.10286586	6.11024953	0.046132
90	0.30945716	4.20799353	0.17077356	4.1576121	8.21866051	0.060417
110	0.42254208	6.23368251	0.12979437	5.19697583	10.230658	0.049407
130	0.23360201	8.25656994	0.18724773	7.26160692	14.3158911	0.051616074
150	0.48142893	9.27413739	0.21441028	7.40822359	12.6344948	0.062116581

Research Question: **Is PBEID Class 2 (µ1) better than (µ2) concerning Propagation Time ?**

µ1: mean (Propagation Time of PBEID Class 2)
µ2: mean (Propagation Time of Autocast/Counter/Distance/Flooding 1 Sec/Flooding 2Sec)

Hypothesized difference (D): 0
Significance level (%): 5
Population variances for the t-test: Assume equality

t-test for two independent samples / Lower-tailed test:

t-test for two independent samples / Lower-tailed test: 95% confidence interval on the difference between the means							
Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
PBEID C2	7	0	7	4.61E-02	1.01E-01	6.44E-02	1.97E-02
Autocast	7	0	7	1.63E-01	4.81E-01	3.12E-01	1.23E-01
PBEID C2	7	0	7	4.61E-02	1.01E-01	6.44E-02	1.97E-02
Counter	7	0	7	2.04E+00	9.27E+00	5.20E+00	2.77E+00
PBEID C2	7	0	7	4.61E-02	1.01E-01	6.44E-02	1.97E-02
Distance	7	0	7	6.74E-02	2.14E-01	1.39E-01	5.38E-02
PBEID C2	7	0	7	4.61E-02	1.01E-01	6.44E-02	1.97E-02
Flooding 1 Sec	7	0	7	2.04E+00	7.41E+00	4.46E+00	2.26E+00
PBEID C2	7	0	7	4.61E-02	1.01E-01	6.44E-02	1.97E-02
Flooding 2 Sec	7	0	7	4.04E+00	1.43E+01	8.52E+00	4.07E+00

H0: The difference between the means is greater or equal to 0, i.e. $\mu1 - \mu2 >= 0$.
Ha: The difference between the means is lower than 0, i.e. $\mu1 - \mu2 < 0$
Significance Value 0.05

Research Conclusion							
PBEID vs	Difference	t (Observed value)	t (Critical value)	DF	p-value (one-tailed)	Rejected Hypothesis	Research Answer
Autocast	-2.48E-01	-5.29E+00	-1.78E+00	12	< 0.0001	H0	**Significantly YES**
Counter	-5.14E+00	-4.91E+00	-1.78E+00	12	1.81E-04	H0	**Significantly YES**
Distance	-7.44E-02	-3.44E+00	-1.78E+00	12	2.46E-03	H0	**Significantly YES**
Flooding 1 Sec	-4.40E+00	-5.15E+00	-1.78E+00	12	1.20E-04	H0	**Significantly YES**
Flooding 2 Sec	-8.45E+00	-5.50E+00	-1.78E+00	12	< 0.0001	H0	**Significantly YES**

4.3.2. Reachability Ratio

4.3.2.1. Statistical Analysis for Class 1 Messages

Table 6: Statistical Analysis for Class 1 Messages w.r.t. Reachability Ratio

Reachability Ratio						
# Node/Technique	Autocast	Counter	Distance	Flooding 1 Sec	Flooding 2 Sec	PBEID Class 1
30	612.1654164	49.02342542	1104.679422	49.02365157	24.7682979	2144.404177
50	530.5264945	31.53618327	1483.501461	48.38405997	24.54779741	1655.993787
70	258.0657415	31.05416516	899.3048374	32.22827042	16.36594373	970.5138483
90	323.146506	23.76429509	585.5707406	24.05226789	12.16743287	991.6109712
110	234.5113393	16.04188212	763.4453566	19.2419598	9.774542361	820.7822054
130	428.0785084	12.111567	534.0518681	13.77105661	6.87777923	1718.767524
150	198.0216131	10.13571355	444.6304223	12.68860191	7.070590059	412.0658405

Research Question: **Is PBEID Class 1 (µ1) better than (µ2) concerning Reachability of nodes?**

µ1: mean (Reachability Ratio of PBEID Class 1)
µ2: mean (Reachability Ratio of Autocast/Counter/Distance/Flooding 1 Sec/Flooding 2Sec)

Hypothesized difference (D): 0
Significance level (%): 5
Population variances for the t-test: Assume equality

t-test for two independent samples / upper-tailed test:

t-test for two independent samples / Lower-tailed test: 95% confidence interval on the difference between the means							
Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
PBEID C1	7	0	7	4.12E+02	2.14E+03	1.24E+03	6.08E+02
Autocast	7	0	7	1.98E+02	6.12E+02	3.69E+02	1.58E+02
PBEID C1	7	0	7	4.12E+02	2.14E+03	1.24E+03	6.08E+02
Counter	7	0	7	1.01E+01	4.90E+01	2.48E+01	1.37E+01
PBEID C1	7	0	7	4.12E+02	2.14E+03	1.24E+03	6.08E+02
Distance	7	0	7	4.45E+02	1.48E+03	8.31E+02	3.67E+02
PBEID C1	7	0	7	4.12E+02	2.14E+03	1.24E+03	6.08E+02
Flooding 1 Sec	7	0	7	1.27E+01	4.90E+01	2.85E+01	1.53E+01
PBEID C1	7	0	7	4.12E+02	2.14E+03	1.24E+03	6.08E+02
Flooding 2 Sec	7	0	7	6.88E+00	2.48E+01	1.45E+01	7.65E+00

H0: The difference between the means is lower or equal to 0, i.e. µ1 - µ2 <= 0.
Ha: The difference between the means is greater than 0, i.e. µ1 - µ2 > 0
Significance Value 0.05

Research Conclusion							
PBEID C1 vs	Difference	t (Observed value)	t (Critical value)	DF	p-value (one-tailed)	Rejected Hypothesis	Research Answer
Autocast	8.76E+02	3.69E+00	1.78E+00	12	1.55E-03	H0	**Significantly YES**
Counter	1.22E+03	5.31E+00	1.78E+00	12	< 0.0001	H0	**Significantly YES**
Distance	4.14E+02	1.54E+00	1.78E+00	12	7.43E-02	Ha	**Significantly NO**
Flooding 1 Sec	1.22E+03	5.29E+00	1.78E+00	12	< 0.0001	H0	**Significantly YES**
Flooding 2 Sec	1.23E+03	5.36E+00	1.78E+00	12	< 0.0001	H0	**Significantly YES**

4.3.2.2. *Statistical Analysis for Class 2 Messages*

Table 7: Statistical Analysis for Class 2 Messages w.r.t. Reachability Ratio

Reachability Ratio						
# Node/Technique	Autocast	Counter	Distance	Flooding 1 Sec	Flooding 2 Sec	PBEID Class 2
30	612.1654164	49.02342542	1104.679422	49.02365157	24.7682979	1247.224925
50	530.5264945	31.53618327	1483.501461	48.38405997	24.54779741	991.6404708
70	258.0657415	31.05416516	899.3048374	32.22827042	16.36594373	2167.692708
90	323.146506	23.76429509	585.5707406	24.05226789	12.16743287	1655.163282
110	234.5113393	16.04188212	763.4453566	19.2419598	9.774542361	2024.004696
130	428.0785084	12.111567	534.0518681	13.77105661	6.87777923	1937.380989
150	198.0216131	10.13571355	444.6304223	12.68860191	7.070590059	1609.876113

Research Question: **Is PBEID Class 2 (μ1) better than (μ2) concerning Reachability of nodes?**

μ1: mean (Reachability Ratio of PBEID Class 2)
μ2: mean (Reachability Ratio of Autocast/Counter/Distance/Flooding 1 Sec/Flooding 2Sec)

Hypothesized difference (D): 0
Significance level (%): 5
Population variances for the t-test: Assume equality

t-test for two independent samples / upper-tailed test:

t-test for two independent samples / Lower-tailed test: 95% confidence interval on the difference between the means							
Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
PBEID C2	7	0	7	9.92E+02	2.17E+03	1.66E+03	4.26E+02
Autocast	7	0	7	1.98E+02	6.12E+02	3.69E+02	1.58E+02
PBEID C2	7	0	7	9.92E+02	2.17E+03	1.66E+03	4.26E+02
Counter	7	0	7	1.01E+01	4.90E+01	2.48E+01	1.37E+01
PBEID C2	7	0	7	9.92E+02	2.17E+03	1.66E+03	4.26E+02
Distance	7	0	7	4.45E+02	1.48E+03	8.31E+02	3.67E+02
PBEID C2	7	0	7	9.92E+02	2.17E+03	1.66E+03	4.26E+02
Flooding 1 Sec	7	0	7	1.27E+01	4.90E+01	2.85E+01	1.53E+01
PBEID C2	7	0	7	9.92E+02	2.17E+03	1.66E+03	4.26E+02
Flooding 2 Sec	7	0	7	6.88E+00	2.48E+01	1.45E+01	7.65E+00

H0: The difference between the means is lower or equal to 0, i.e. μ1 - μ2 <= 0.
Ha: The difference between the means is greater than 0, i.e. μ1 - μ2 > 0
Significance Value 0.05

Research Conclusion							
PBEID C2 vs	Difference	t (Observed value)	t (Critical value)	DF	p-value (one-tailed)	Rejected Hypothesis	Research Answer
Autocast	1.29E+03	7.53E+00	1.78E+00	12	< 0.0001	H0	**Significantly YES**
Counter	1.64E+03	1.02E+01	1.78E+00	12	< 0.0001	H0	**Significantly YES**
Distance	8.31E+02	3.91E+00	1.78E+00	12	1.03E-03	H0	**Significantly YES**
Flooding 1 Sec	1.63E+03	1.01E+01	1.78E+00	12	< 0.0001	H0	**Significantly YES**
Flooding 2 Sec	1.65E+03	1.02E+01	1.78E+00	12	< 0.0001	H0	**Significantly YES**

4.3.3. Packet Generated

4.3.3.1. Statistical Analysis for Class 1 Messages

Table 8: Statistical Analysis for Class 1 Messages w.r.t. Packet Generated

Retransmission of Packet						
# Node/Technique	Autocast	Counter	Distance	Flooding 1 Sec	Flooding 2 Sec	PBEID Class 1
30	17	9	25	30	30	3
50	26	12	45	50	50	4
70	34	16	65	70	70	5
90	38	18	85	90	90	6
110	57	20	104	110	110	6
130	72	20	125	130	128	10
150	65	20	138	141	118	10

Research Question: **Is PBEID Class 1 (µ1) better than (µ2) concerning number of packet Generated in the network ?**

µ1: mean (Packet Generated in PBEID Class 1)
µ2: mean (Packet Generated in Autocast/Counter/Distance/Flooding 1 Sec/Flooding 2Sec)

Hypothesized difference (D): 0
Significance level (%): 5
Population variances for the t-test: Assume equality

t-test for two independent samples / Lower-tailed test:

t-test for two independent samples / Lower-tailed test: 95% confidence interval on the difference between the means							
Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
PBEID C1	7	0	7	3.00E+00	1.00E+01	6.29E+00	2.75E+00
Autocast	7	0	7	1.70E+01	7.20E+01	4.41E+01	2.07E+01
PBEID C1	7	0	7	3.00E+00	1.00E+01	6.29E+00	2.75E+00
Counter	7	0	7	9.00E+00	2.00E+01	1.64E+01	4.39E+00
PBEID C1	7	0	7	3.00E+00	1.00E+01	6.29E+00	2.75E+00
Distance	7	0	7	2.50E+01	1.38E+02	8.39E+01	4.16E+01
PBEID C1	7	0	7	3.00E+00	1.00E+01	6.29E+00	2.75E+00
Flooding 1 Sec	7	0	7	3.00E+01	1.41E+02	8.87E+01	4.12E+01
PBEID C1	7	0	7	3.00E+00	1.00E+01	6.29E+00	2.75E+00
Flooding 2 Sec	7	0	7	3.00E+01	1.28E+02	8.51E+01	3.67E+01

H0: The difference between the means is greater or equal to 0, i.e. µ1 - µ2 >= 0.
Ha: The difference between the means is lower than 0, i.e. µ1 - µ2 < 0
Significance Value 0.05

Research Conclusion							
PBEID C1 vs	Difference	t (Observed value)	t (Critical value)	DF	p-value (one-tailed)	Rejected Hypothesis	Research Answer
Autocast	-3.79E+01	-4.79E+00	-1.78E+00	12	2.22E-04	H0	**Significantly YES**
Counter	-1.01E+01	-5.18E+00	-1.78E+00	12	1.15E-04	H0	**Significantly YES**
Distance	-7.76E+01	-4.93E+00	-1.78E+00	12	1.75E-04	H0	**Significantly YES**
Flooding 1 Sec	-8.24E+01	-5.28E+00	-1.78E+00	12	< 0.0001	H0	**Significantly YES**
Flooding 2 Sec	-7.89E+01	-5.68E+00	-1.78E+00	12	< 0.0001	H0	**Significantly YES**

4.3.3.2. *Statistical Analysis for Class 2 Messages*

Table 9: Statistical Analysis for Class 2 Messages w.r.t. Packet Generated

Retransmission of Packet						
# Node/Technique	Autocast	Counter	Distance	Flooding 1 Sec	Flooding 2 Sec	PBEID Class 1
30	17	9	25	30	30	4
50	26	12	45	50	50	5
70	34	16	65	70	70	5
90	38	18	85	90	90	4
110	57	20	104	110	110	4
130	72	20	125	130	128	4
150	65	20	138	141	118	4

Research Question: **Is PBEID Class 2 (µ1) better than (µ2) concerning number of packet Generated in the network ?**

µ1: mean (Packet Generated in PBEID Class 2)
µ2: mean (Packet Generated in Autocast/Counter/Distance/Flooding 1 Sec/Flooding 2Sec)

Hypothesized difference (D): 0
Significance level (%): 5
Population variances for the t-test: Assume equality

t-test for two independent samples / Lower-tailed test:

t-test for two independent samples / Lower-tailed test: 95% confidence interval on the difference between the means							
Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
PBEID C2	7	0	7	4.00E+00	5.00E+00	4.29E+00	4.88E-01
Autocast	7	0	7	1.70E+01	7.20E+01	4.41E+01	2.07E+01
PBEID C2	7	0	7	4.00E+00	5.00E+00	4.29E+00	4.88E-01
Counter	7	0	7	9.00E+00	2.00E+01	1.64E+01	4.39E+00
PBEID C2	7	0	7	4.00E+00	5.00E+00	4.29E+00	4.88E-01
Distance	7	0	7	2.50E+01	1.38E+02	8.39E+01	4.16E+01
PBEID C2	7	0	7	4.00E+00	5.00E+00	4.29E+00	4.88E-01
Flooding 1 Sec	7	0	7	3.00E+01	1.41E+02	8.87E+01	4.12E+01
PBEID C2	7	0	7	4.00E+00	5.00E+00	4.29E+00	4.88E-01
Flooding 2 Sec	7	0	7	3.00E+01	1.28E+02	8.51E+01	3.67E+01

H0: The difference between the means is greater or equal to 0, i.e. $\mu1 - \mu2 >= 0$.
Ha: The difference between the means is lower than 0, i.e. $\mu1 - \mu2 < 0$
Significance Value 0.05

Research Conclusion							
PBEID C2 vs	Difference	t (Observed value)	t (Critical value)	DF	p-value (one-tailed)	Rejected Hypothesis	Research Answer
Autocast	-3.99E+01	-5.08E+00	-1.78E+00	12	1.35E-04	H0	**Significantly YES**
Counter	-1.21E+01	-7.27E+00	-1.78E+00	12	< 0.0001	H0	**Significantly YES**
Distance	-7.96E+01	-5.07E+00	-1.78E+00	12	1.39E-04	H0	**Significantly YES**
Flooding 1 Sec	-8.44E+01	-5.42E+00	-1.78E+00	12	< 0.0001	H0	**Significantly YES**
Flooding 2 Sec	-8.09E+01	-5.84E+00	-1.78E+00	12	< 0.0001	H0	**Significantly YES**

4.3.4. Total Packet Loss

4.3.4.1. Statistical Analysis for Class 1 Messages

Table 10: Statistical Analysis for Class 1 Messages w.r.t. Total Packet Loss

Total Packet Loss						
# Node/Technique	Autocast	Counter	Distance	Flooding 1 Sec	Flooding 2 Sec	PBEID Class 1
30	0	0	0	0	0	0
50	38	63	40	39	38	13
70	34	28	28	28	28	14
90	104	103	156	103	104	64
110	120	120	154	178	150	50
130	111	73	163	71	71	17
150	129	116	240	133	104	36

Research Question: **Is PBEID Class 1 (μ1) better than (μ2) concerning the packet loss in network ?**

μ1: mean (Total Packet Loss of PBEID Class 1)
μ2: mean (Total Packet Loss of Autocast/Counter/Distance/Flooding 1 Sec/Flooding 2Sec)

Hypothesized difference (D):	0
Significance level (%):	5
Population variances for the t-test:	Assume equality

t-test for two independent samples / Lower-tailed test:

t-test for two independent samples / Lower-tailed test: 95% confidence interval on the difference between the means							
Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
PBEID C1	6	0	6	1.30E+01	6.40E+01	3.23E+01	2.13E+01
Autocast	6	0	6	3.40E+01	1.29E+02	8.93E+01	4.22E+01
PBEID C1	6	0	6	1.30E+01	6.40E+01	3.23E+01	2.13E+01
Counter	6	0	6	2.80E+01	1.20E+02	8.38E+01	3.57E+01
PBEID C1	6	0	6	1.30E+01	6.40E+01	3.23E+01	2.13E+01
Distance	6	0	6	2.80E+01	2.40E+02	1.30E+02	8.12E+01
PBEID C1	6	0	6	1.30E+01	6.40E+01	3.23E+01	2.13E+01
Flooding 1 Sec	6	0	6	2.80E+01	1.78E+02	9.20E+01	5.75E+01
PBEID C1	6	0	6	1.30E+01	6.40E+01	3.23E+01	2.13E+01
Flooding 2 Sec	6	0	6	2.80E+01	1.50E+02	8.25E+01	4.60E+01

H0: The difference between the means is greater or equal to 0, i.e. μ1 - μ2 >= 0.
Ha: The difference between the means is lower than 0, i.e. μ1 - μ2 < 0
Significance Value 0.05

Research Conclusion							
PBEID C1 vs	Difference	t (Observed value)	t (Critical value)	DF	p-value (one-tailed)	Rejected Hypothesis	Research Answer
Autocast	-5.70E+01	-2.95E+00	-1.81E+00	10	7.22E-03	H0	**Significantly YES**
Counter	-5.15E+01	-3.03E+00	-1.81E+00	10	6.31E-03	H0	**Significantly YES**
Distance	-9.78E+01	-2.86E+00	-1.81E+00	10	8.55E-03	H0	**Significantly YES**
Flooding 1 Sec	-5.97E+01	-2.38E+00	-1.81E+00	10	1.92E-02	H0	**Significantly YES**
Flooding 2 Sec	-5.02E+01	-2.43E+00	-1.81E+00	10	1.79E-02	H0	**Significantly YES**

4.3.4.2. *Statistical Analysis for Class 2 Messages*

Table 11: Statistical Analysis for Class 2 Messages w.r.t. Total Packet Loss

Total Packet Loss						
# Node/Technique	Autocast	Counter	Distance	Flooding 1 Sec	Flooding 2 Sec	PBEID Class 2
30	0	0	0	0	0	**0**
50	38	63	40	39	38	**26**
70	34	28	28	28	28	**16**
90	104	103	156	103	104	**42**
110	120	120	154	178	150	**64**
130	111	73	163	71	71	**56**
150	129	116	240	133	104	**63**

Research Question:	**Is PBEID Class 2 (µ1) better than (µ2) concerning the packet loss in network ?**

µ1: mean (Total Packet Loss of PBEID Class 2)
µ2: mean (Total Packet Loss of Autocast/Counter/Distance/Flooding 1 Sec/Flooding 2Sec)

Hypothesized difference (D):	0
Significance level (%):	5
Population variances for the t-test:	Assume equality

t-test for two independent samples / Lower-tailed test:

t-test for two independent samples / Lower-tailed test: 95% confidence interval on the difference between the means							
Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
PBEID C2	6	0	6	1.60E+01	6.40E+01	4.45E+01	2.01E+01
Autocast	6	0	6	3.40E+01	1.29E+02	8.93E+01	4.22E+01
PBEID C2	6	0	6	1.60E+01	6.40E+01	4.45E+01	2.01E+01
Counter	6	0	6	2.80E+01	1.20E+02	8.38E+01	3.57E+01
PBEID C2	6	0	6	1.60E+01	6.40E+01	4.45E+01	2.01E+01
Distance	6	0	6	2.80E+01	2.40E+02	1.30E+02	8.12E+01
PBEID C2	6	0	6	1.60E+01	6.40E+01	4.45E+01	2.01E+01
Flooding 1 Sec	6	0	6	2.80E+01	1.78E+02	9.20E+01	5.75E+01
PBEID C2	6	0	6	1.60E+01	6.40E+01	4.45E+01	2.01E+01
Flooding 2 Sec	6	0	6	2.80E+01	1.50E+02	8.25E+01	4.60E+01

H0:	The difference between the means is greater or equal to 0, i.e. $\mu1 - \mu2 >= 0$.
Ha:	The difference between the means is lower than 0, i.e. $\mu1 - \mu2 < 0$
Significance Value	0.05

Research Conclusion							
PBEID C2 vs	Difference	t (Observed value)	t (Critical value)	DF	p-value (one-tailed)	Rejected Hypothesis	Research Answer
Autocast	-4.48E+01	-2.35E+00	-1.81E+00	10	2.03E-02	H0	**Significantly YES**
Counter	-3.93E+01	-2.35E+00	-1.81E+00	10	2.03E-02	H0	**Significantly YES**
Distance	-8.57E+01	-2.51E+00	-1.81E+00	10	1.55E-02	H0	**Significantly YES**
Flooding 1 Sec	-4.75E+01	-1.91E+00	-1.81E+00	10	4.26E-02	H0	**Significantly YES**
Flooding 2 Sec	-3.80E+01	-1.86E+00	-1.81E+00	10	4.66E-02	H0	**Significantly YES**

5. Conclusion

In this work, we have explained various techniques available for information dissemination in VANETs. We further proposed a Priority based Efficient Information Dissemination (PBeiD) protocol. The protocol and its core concepts are discussed in detail. The proposed protocol is compared with benchmark protocols, and the simulation is carried out based on different scenarios from sparse to dense. We found that our protocol is performing well in almost all the cases and to provide proper justification that our results are significant and not by chance, we applied statistical t-test on the results obtained. As future work, we will analyse the performance of PBeiD in more complex scenarios. Our primary interest is to study the behaviour of our protocol when there are multiple messages in the network. More work will be carried out in the making α adaptive to calculate density in a real scenario. With these findings, we may conclude further that PBeiD will work in more complex scenarios.

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Figures

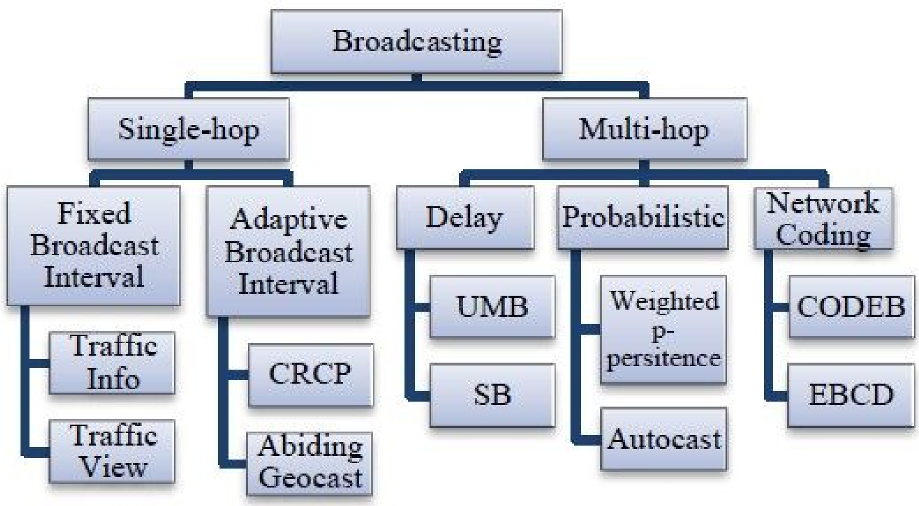

Figure 1

Classification of popular Information Dissemination protocol

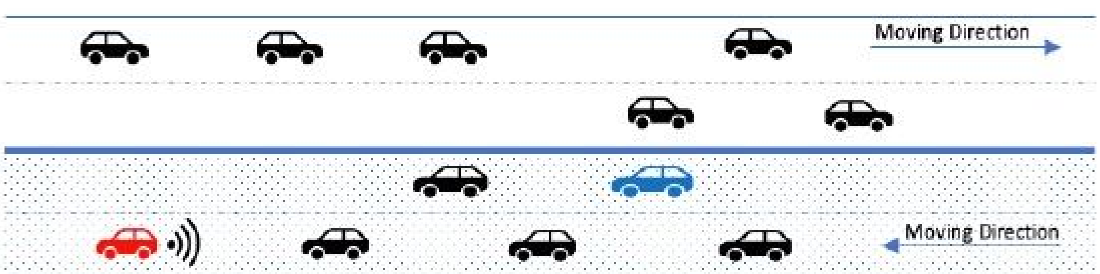

Figure 2

Class 1 & Class 3 Message, Backward Broadcast

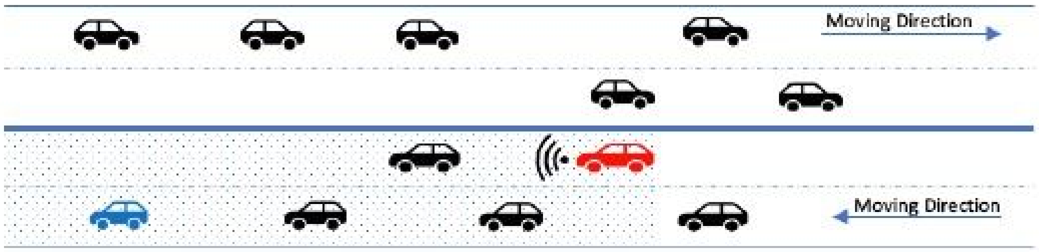

Figure 3

Class 2 & 4 Message, Forward Broadcast

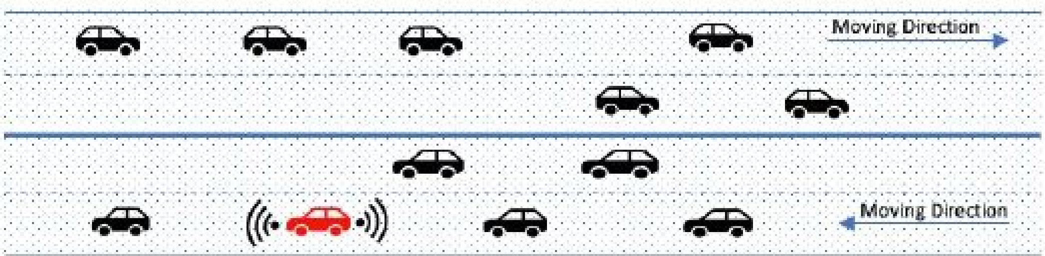

Figure 4

Class 5 Message, General Broadcast

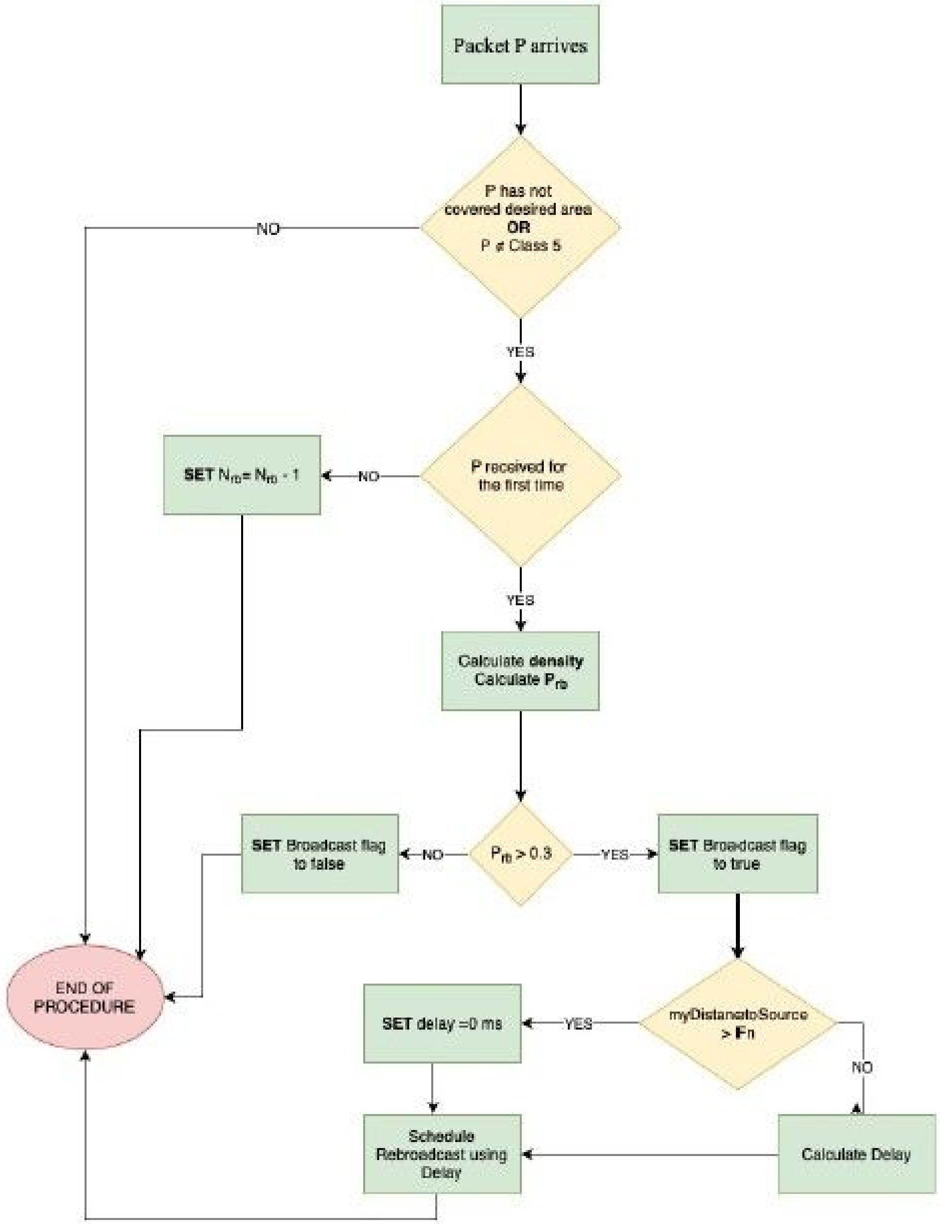

Figure 5

Flowchart of Receive Packet in PBeiD

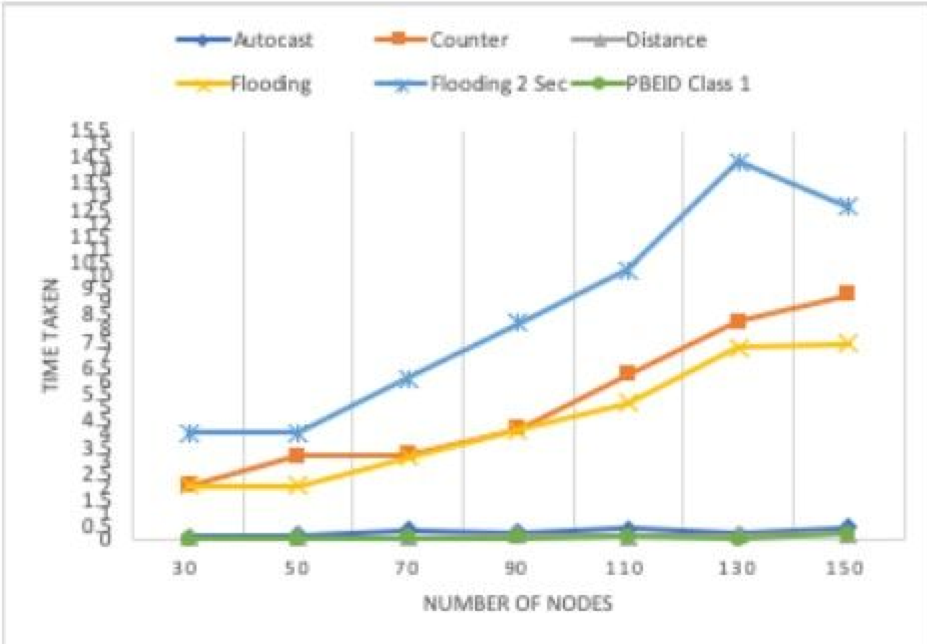

Figure 6

Number of Nodes vs Propagation in Time Class 1 Messages

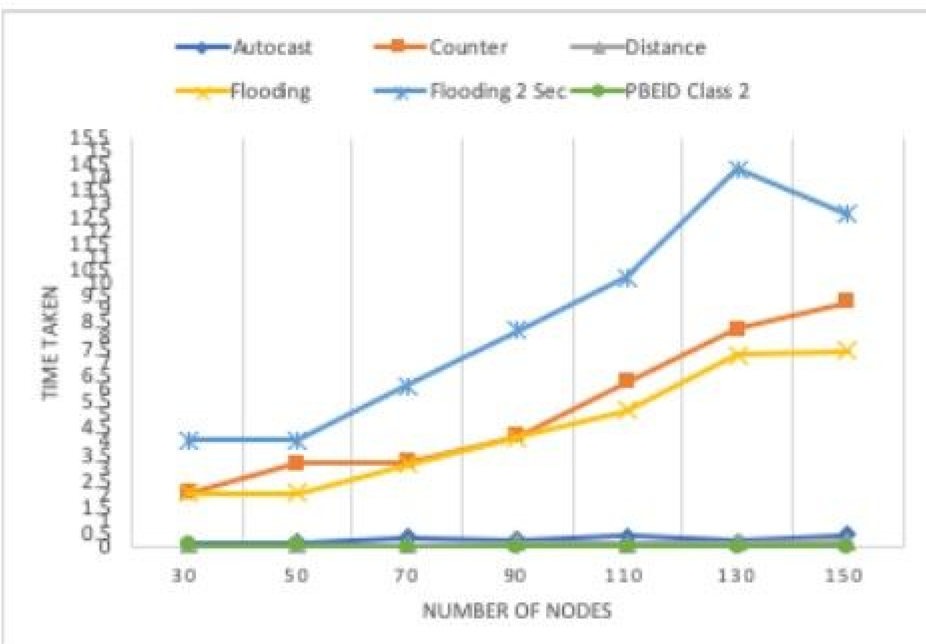

Figure 7

Number of Nodes vs Propagation in Time Class 2 Messages

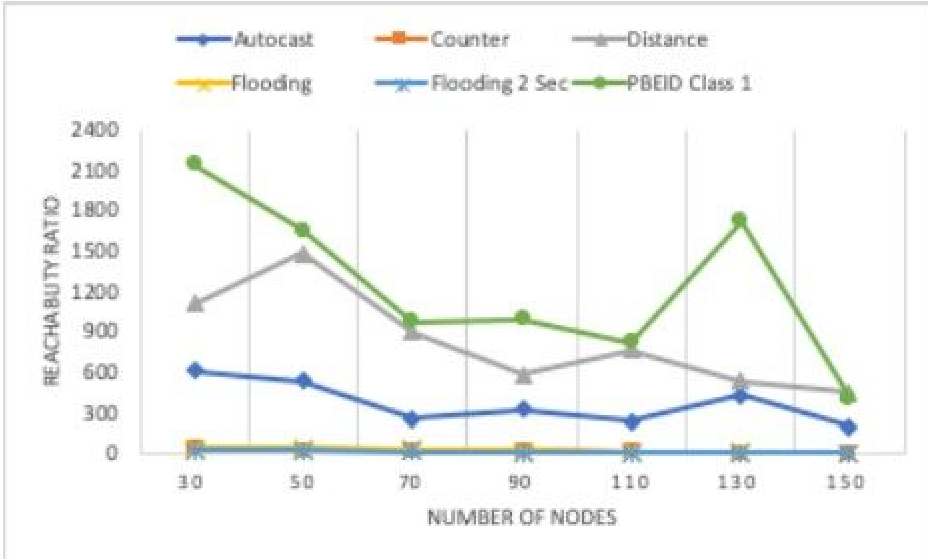

Figure 8

Number of Nodes vs Reachability Ratio Class 1 Messages

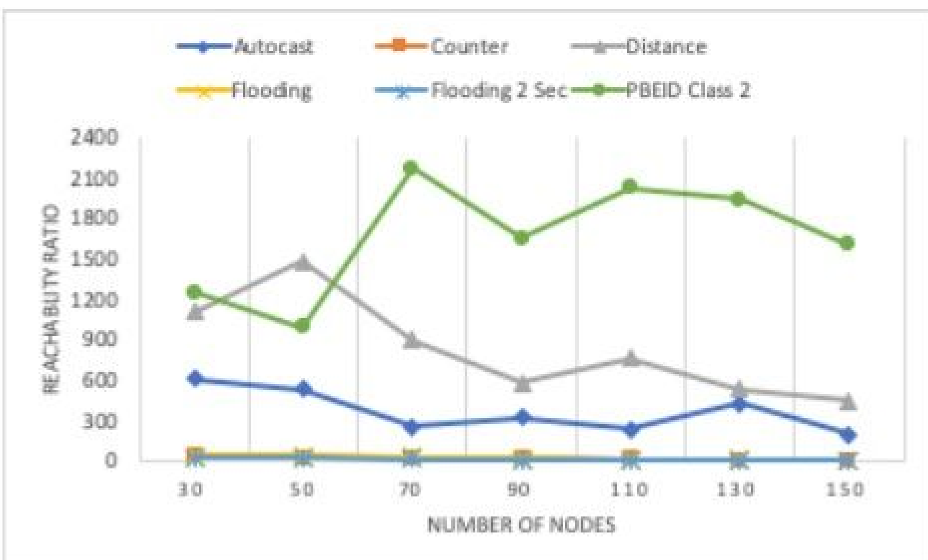

Figure 9

Number of Nodes vs Reachability Ratio Class 2 Messages

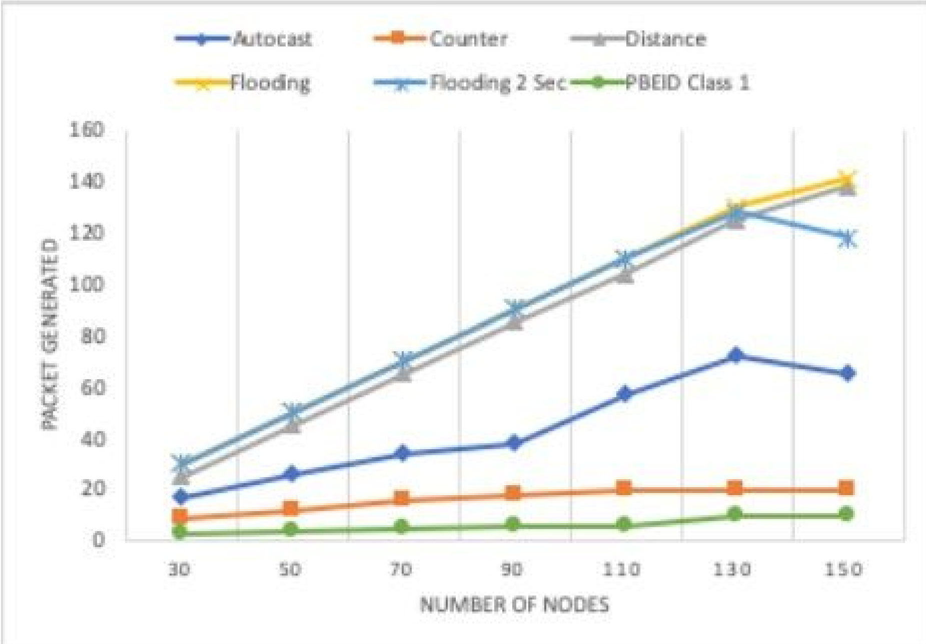

Figure 10

Number of Nodes vs Packet Generated in Class 1

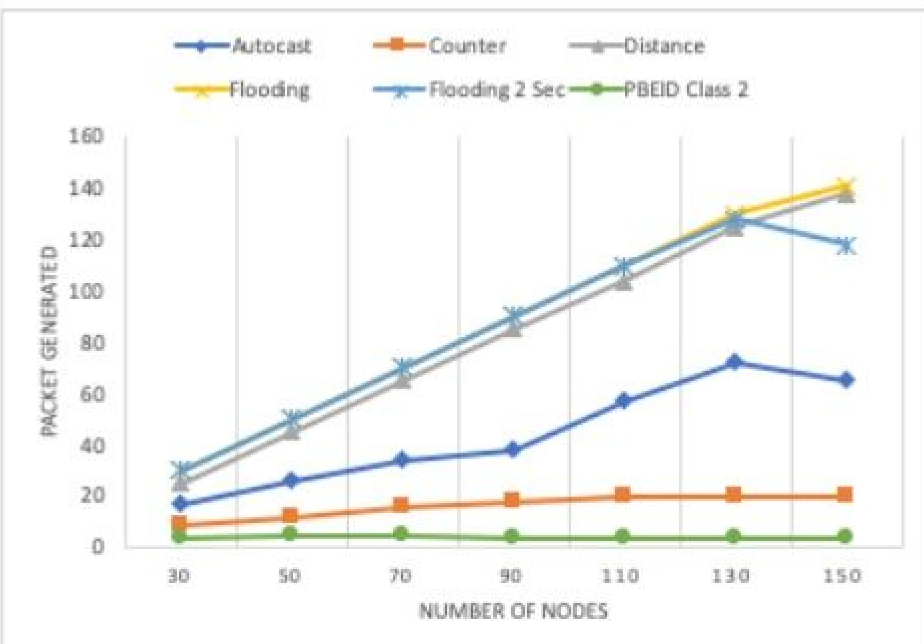

Figure 11

Number of Nodes vs Packet Generated in Class 2

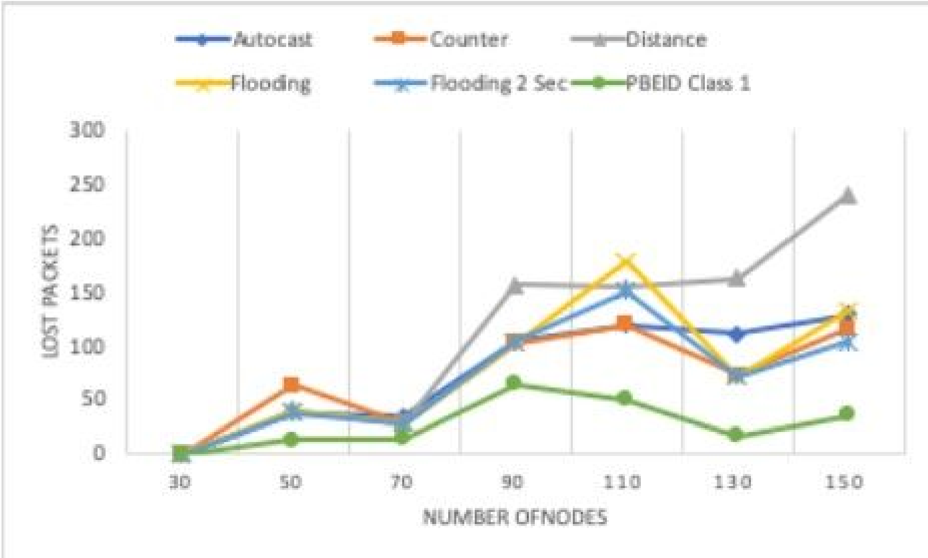

Figure 12

Number of Nodes vs Rx Tx Lost Packets Class 1 Messages

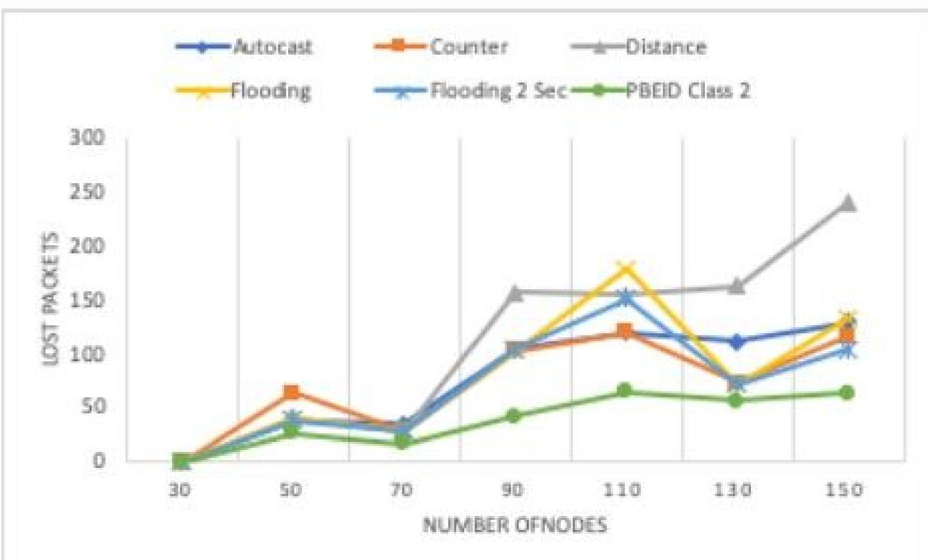

Figure 13

Number of Nodes vs Rx Tx Lost Packets Class 2 Messages