Simulation of Automatic Emergency Electronic Braking System

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***Abstract* - Vehicular ad-hoc networks (VANETs) are implemented for safe vehicular transportation based on communication between vehicles using ad-hoc networks. This work proposes a simulation study of an emergency braking (EB) application accomplished by car dynamics and drivers' behaviour models using network simulator (NS3). The proposed system will represent the interactions with the vehicle's automatic braking system (ABS) and the driver's behaviour model (using Intelligent Driving Model). This work proposes a unique message aggregation mechanism for packet re-broadcast while managing the network congestion during the peak load due to hard braking. This work is useful even when the cars which are not equipped with ABS benefits smooth driving when they are in between cars which are equipped with ABS.**

I. Introduction

Today the most emerging wireless technology is vehicular ad-hoc networks (VANETs). The vehicular ad-hoc network uses vehicles as nodes with mobility to create a mobile network. A VANET converts every vehicle into a router or wireless node, allowing vehicles 100 to 300 metres apart from each other to connect. This creates a wide range of network, so each vehicle will have its own ad-hoc network which ranges from 100 to 300 metres which is useful for communicating between vehicles. The main objective of communication between vehicles is to ensure safe driving which avoids vehicle collisions due to hard brake by the lead vehicle.

Each VANET will act as node with mobility. The road system has several disadvantages regarding vehicle accidents in which some can be overcome using VANETs. Vehicles with VANET technology in it can avoid collisions at road intersections and highways.

The VANET communication techniques are of two types: Vehicle to vehicle communication takes place between two vehicles when they fall in between each other's ad-hoc network. When ad-hoc networks of two vehicles intersect the intermediate network will be formed using which the messages can be sent and received. Vehicle-to-Vehicle communication will ensure co-operative driving and information sharing. If a vehicle on road slowdowns suddenly then that message will be broadcasted to all the vehicles with in the network. The vehicles which receive that message will have enough time to avoid collision and can take the shortest path on road by managing the speed.

The vehicle to infrastructure communication is same as vehicle to vehicle communication. The vehicle to vehicle communication is done between two vehicles whose ad-hoc network intersects and then they can send and receive messages but, in vehicle to infrastructure communication the range of communication is high. The road side units (RSU) are placed beside road with 500m to 1km range. The vehicles which fall under range of road side units can communicate with each other with the help of road side units and even the vehicles which are not in the range of that particular RSU can be communicated. This will ensure message sharing.

The vehicles on highway will move at high speed. The speed of the vehicles which is in the range of 80 to 120 kmph should apply brakes to get in to complete stop. The deceleration of the vehicles more than 10 m/s^2 will cause the hard brake whose impact is equal to accidents. Therefore the vehicle should apply brake with constant deceleration below 10 m/s^2. The automatic braking system will automate the braking system, the vehicle automatically apply brake if driver did not react with in safe time.

The automatic emergency braking system will reduce accidents due to sudden brake of leading vehicle by sending emergency braking messages to all vehicles which are being affected by particular hard brake. To avoid vehicle accidents due to hard brake on road, platooning technique is used. The platooning technique uses adaptive cruise control. The vehicles on highways will move one after the other. Each platoon will have its platoon head. Platoon head always should be a truck or heavy vehicle. The platoon members should not overtake platoon head. The platoon head will move in particular speed in which all other vehicles should manage the speed with respect to platoon head with the help of adaptive cruise control but this technique is complex to implement, because platooning requires a heavy vehicle to lead all vehicles in platoon.

To avoid the complexity with platooning, different approaches using VANET technology have been developed. One among them is emergency braking, which is a simple safety application. Here, adaptive cruise control (ACC) will be used to manage the vehicles in accident zone if driver doesn't intervene. Adaptive Cruise Control (ACC) is an automatic form of cruise control system that slows down and speeds up vehicle automatically to manage relative velocity with the leading vehicle. The driver sets maximum speed same as in cruise control and then radar sensor looks for traffic ahead, locks the speed to the leading vehicle in a lane, and instructs the vehicle to stay particular distance behind the leading vehicle. This will ensure maximum vehicles flow on limited space on road.

The vehicles with ad-hoc network will connect to the other vehicle with VANET technology when they fall in to range of ad-hoc networks each other. The information such as speed of the vehicle, GPS co-ordinates of vehicle, direction of vehicle, and lane in which vehicle is moving is shared with each other. The vehicles will broadcast the information with certain time stamp attached to it. Any message which received or processed after the time stamp is useless. The leading vehicles will broadcast brake message and the following vehicles will receive and processes it. The vehicles will ignore the brake messages from the vehicles with different lane number and messages from vehicles in opposite direction. The vehicle will trigger the brake once it receives the valid brake message with in specified time stamp.

II. RELATED WORK

The protocols emergency electronic braking with aggregation (EEBA) and emergency electronic braking with rebroadcast (EEBR) are introduced in [1] which will process brake message and broadcast the brake message to other vehicles. This work will present simulative results on vehicles on highway by taking crashes due to hard brake into account. The vehicles move in high speed on their respective lanes, and for possible reasons if leading vehicles applied the brake then all vehicles has to follow the leading vehicles and apply the brake to avoid collision.

The work will suggest the EEBR algorithm which will processes the unique brake message and rebroadcast the same brake message to other vehicles in the lane.Vehicle platooning [2], [3] is not applicable in all scenarios because of its huge cost and space complexity. Vehicle platooning is grouping vehicles into platoon, which increases capacity of road. This will allow many vehicles to brake and accelerate simultaneously. The vehicles will move in platoons and each platoon will have a platoon head. The platoon head should always be a heavy vehicle like truck or bus. The platoon head driver should have a valid license to drive it and need extra skills to lead the platoon and proper training should be given. The vehicles following platoon head will accelerate and decelerate with respect to the platoon head. But for safety reasons it's always a critical situation a car traveling between two heavy vehicles.

The biggest issue with emergency electronic braking is to broadcast safety information without congestion in the network. Gossiping-based protocols and clustering algorithms are some solutions proposed so far as these can adapt to traffic or wireless channel conditions as specified in [4]–[7]. These approaches reach significant levels of performance in terms of network results. But the vehicle dynamics are not considered.In [7], a new protocol for communication between car to car and car to infrastructure (like base stations, mobile or any communicating device), Adaptive Traffic Beacon (ATB), which progresses by providing a system architecture that adapts by itself to various situations and constraints are presented. Adaptive Traffic Beacon is mainly based on a beaconing. Vehicle density, vehicles' velocity and delay are taken into account. ATB is adaptive; it automatically manages available RSUs or centralized communicative services also.Rebroadcast protocols, presented in [8], broadcasting will solve many issues of MANETs especially host mobility such as finding route to some host, messaging and sending alarm signal are most frequently done operation. Because there will be a case of overlapping the signals of radios in same physical areas. The direct flooding of the signals to particular host will cost in useless usage of signal, variances and crash which is called broadcast storm problem.

The technique proposed in the [9] will keep channel usability under control and spread the information very quickly, but challenges such as "time to re-broadcast message?" or "what is the range of re-broadcast needed?" have never been taken into consideration. The algorithm developed by Ibrahim and Weigle in [10] will present the procedure for exact aggregation of data packets which contain traffic information. The traffic messages broadcasted by the vehicles will help the vehicles behind to get the exact scenario of the traffic ahead in the path. This method of receiving the message regarding the traffic flow of the road will help in co-operative driving. A specific lane change [11] , depends on the two following vehicles in the current lane and the target lanes, respectively. To calculate the lane changing criteria for a vehicle c assuming a lane change, the leading vehicles in the target and current lanes are considered.

The "Highway Co-operative Collision Avoidance" (CCA) [12], is an emerging vehicle security scheme exploiting DSRC standard. The description of the DSRC architecture, the concepts of CCA is introduced and its needs for implementation in the vehicle to vehicle wireless scenarios. In [13], the description of first implementation of a vehicle mobility model combined with the functions in ns-3. Combined VANET simulators which include both mobility and network models are needed, accepting network interactions to affect vehicle mobility, which is one of the goals of future VANET development. Using network messages the drivers can slow down or even can take a different path.

The methods to enable the communication requirements of simultaneous applications are developed in [13] and [14]. The work in [13] is totally on network metrics, the work in [14] is on a higher layer, considering dependence between the applications. Some research on emergencies is listed by Willke et al. [14]. Anyhow they are aware of dynamics and human behaviours, but network details, such as employed physical layers and medium access control (MAC) layers are not taken into account ..

III. EXISTING SYSTEM

The vehicles on highways move at high speed, the vehicles move one after the other on highway. The platoon head will lead the platoon. All other vehicles on that lane have to follow the platoon head. The accidents in this scenario take place due to hard brake applied by lead vehicle. The vehicles have to apply brake with in safe time and safe distance to avoid collision with front vehicle.

The existing systems are of two types:

A. Manual braking system.
B. Automatic braking system.

A. Manual Braking System

The manual braking system is widely used and oldest method of applying brake to the vehicle. The driver of the respective vehicles should apply the brake of the vehicle by noticing obstacle in vehicles path. The vehicle's accidents on highways are mainly caused by sudden brakes of the leading vehicle. The driver of the vehicle should notice leading vehicle's hard brake and need to apply his/her vehicle's brake to avoid collision. The time taken to notice the brake light of leading vehicle and apply brake of his/her vehicle is to large which may lead too collision. This will lead the vehicles to collide with front vehicles and get damaged. According to DOT (Department Of Transportation) survey in USA, the deceleration of the current vehicles should not be more than 10, because deceleration more than 10 will cause effect of accident in the car.

B. Automatic Braking System

The automatic braking system will automate braking mechanism of the vehicle. Most of the vehicle manufacturing companies are implementing VANET technology in the vehicle to automate braking system. The VANET will consider each vehicle as a node with mobility and ad-hoc network on it. If any vehicle with ad-hoc network approaches each other, then an intermediate network will be created. The communication between two vehicles can be established when two ad-hoc network intersects. The vehicles which apply brake will broadcast brake message to other vehicles on the road. The vehicle which receives the brake message will manage its speed and broadcast same message with the help of EEBR protocol. This process may avoid collision but multiple copies of same brake message will be processed and broadcast which will decrease network efficiency. The channel load will be high and percentage of packets lost at each station is also high.

IV. PROPOSED SYSTEM

The vehicle manufacturers are manufacturing their vehicles with VANET technology in it. The VANET will consider each vehicle as node with mobility and ad-hoc network. The vehicles on highway cause accidents due to hard brakes applied by the front vehicle. The vehicles move in platoons on highway. Each vehicle should have VANET technology implemented in it. When the front vehicles at the front apply brake the brake message will be broadcasted by the front vehicle. The following vehicles following it will capture the brake message and processes it and then that brake message will be broadcasted again.

The VANET technologies developed so far exhibits ambiguity during message sending mechanism. The problem is that messages are neither received nor recognized. These problems occurs when we use EEBR protocol because, it broadcast all the messages into the network which causes network congestion, to overcome that we need emergency electronic braking with aggregation (EEBA) protocol.

The EEBA protocol will check whether the received brake message is a new one or already received one by matching the packet ID of message with stored set of packet IDs. The knownpacket queue will store the packet IDs which is already processed by the system. If the received packet ID already exists in the knownpacket queue then it is deleted. If the packet ID doesn't match then it is added to the knownpacket and forwarded for ABS.

The ABS will apply brake and will check for TTL criteria. If the TTL=0, then message will not broadcast. If the TTL is greater than zero then it will be decremented by one value and message will be broadcasted. The messages will be aggregated with the help of sendqueue. The sendqueue is used to store all the brake messages which have already been broadcast by the system.

The figure 1 shows the system architecture of the ABS. the automatic braking system will take control of the vehicle if the vehicle's distance from its front vehicle is less than the safety distance. The car driving system will check whether the vehicle speeding up or slowing down. Emergency braking system will apply brake if the driver doesn't react to the message of the emergency braking system. The automatic braking system will control the message transmission and manages the braking system of the vehicle.

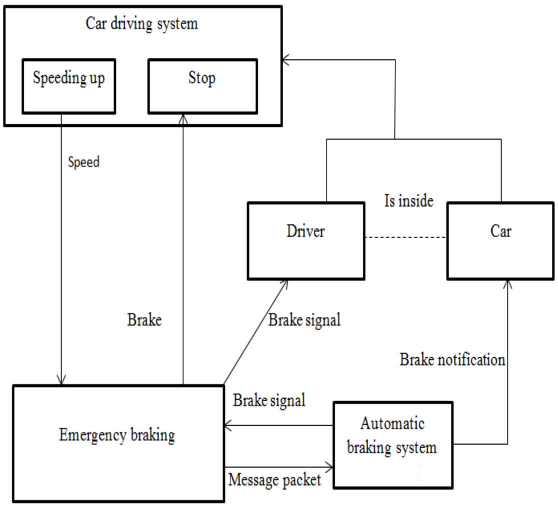

Fig 1: System Architecture

V. IMPLEMENTATION

The basic concept is the vehicle following platoon head should not overtake the platoon head so the platoon head of all lanes will move in same speed and same position of respective lane. If the platoon head is differed in its position then there is chance of the vehicle overtaking the platoon head by lane change function. All the vehicles in the simulation should have VANET technology implemented in it. The vehicles are added in to scene automatically by specifying number of vehicles in command line. Number of vehicles specified plus platoon head is added in to scene. Vehicles will be added when the previously added vehicles creates safe gap pre-specified by user.

The EEBR algorithm firstly sets the highway scenario. The brake of vehicles is applied until they get in to an absolute stop due to an accident or whatever other impairment forcing all vehicles behind to come to an absolute stop too. The leading vehicle on the road will broadcast the brake message. The brake messages are captured by following vehicle and checks whether brake message is new or not. If the brake message is new, then the packet id of the brake message is stored in known packet queue. The brake of vehicle is applied then the check for TTL value is done. The TTL value will have maximum of 5. The TTL value should be more than zero to start rebroadcast of brake message. If the TTL value is more than zero then, the TTL value is decremented by one value and the rebroadcast of brake messages are done.

Algorithms: Emergency electronic braking system with rebroadcast (EEBR):

1. List knownpackets
2. On initprogram ()
3. Knownpackets;
4. on ReceiveEEBLpacket (eebl);
5. If knownpacket.contain (eebl);
6. Return
7. Else
8. Knownpackets.insert (eebl);
9. Processpacket (eebl);
10. If eebl.ttl=0 then
11. eebl.ttl=eebl.ttl-1;
12. broadcast (eebl);
13. End if
14. End if
15. End if

The EEBA algorithm steps are same as EEBR but, the EEBA algorithm will aggregate brake message. Once the leading vehicles broadcasts the brake messages, the brake messages are received and checked whether the received brake message is already processed or not. If it is appeared for the first time then the packet ID is stored in known packet queue and the brake of vehicle is applied. The TTL value is checked whether it is more than zero or equal to zero.

The sendqueue is used for storing the broadcasted brake messages. If TTL value is more than zero then the brake message is inserted into the send queue and the TTL value is decremented by one value. The send queue size is checked for its size, if the send queue size is 1 then only one message is broadcasted without aggregation, if send queue size is more than zero then aggregation of brake messages is done. The aggregation of brake message is done by updating the sender id, TTL and count of brake messages. The broadcast of aggregated brake message is done

Algorithms: Emergency electronic braking system with aggregation:

1. List knownpackets, sendqueue
2. On initprogram ();
3. Knownpackets=∅; sendqueue=∅
4. ScheduleEvent (SendPackets, 100 ms)
5. on ReceiveAggregatedEEBPacket (aggregatedeebl);
6. for all eebl in aggregatedeebl do
7. ReceiveEEBPacket (eebl)
8. End for
9. ReceiveEEBPacket (eebl):
10. If Knownpacket.contain (eebl)
11. If SendQueue.Contains (eebl) then
12. SendQueue.Remove (eebl)
13. End if
14. Return
15. Else
16. Knownpackets.insert (eebl)
17. ProcessPacket (eebl)
18. If eebl.ttl!=0 then
19. eebl.ttl=eebl.ttl-1
20. SendQueue.insert (eebl)
21. End if
22. End if
23. End if
24. On sendPackets ();

```
If SendQueue.Size ()=0 then
If SendQueue.Size ()=1 then
Packet=SendQueue.Get (0)
Else
Packet= CreateAggregatedPacket (Sendqueue)
End if
Broadcast (packet)
SendQueue.Empty ()
End if
ScheduleEvent (SendPackets, 100 ms)
```

VI. SIMULATION PARAMETER

The simulation scenario considered is fundamental highway scenario. The vehicle in the scene will move in platoon. The brake message broadcasted has certain fields which are described in table 1.

Table 1: Description of the fields of EEB messages

Field	Size (B)
Type	1
Originator ID	4
Sender ID	4
Certificate	58
Packet ID	4
TTL	1
Count	1
Digital signature	28

Intelligent driver model is the model which used to specify the characteristics of driver of the vehicles. The IDM model will use two parameters to specify the behavior of the driver. The complete driver behavior can be classified in to two groups, firstly the politeness of the driver which is known as P value of the IDM. The P values ranges between [0, 1]. The driver with the P value closer to zero will follow the traffic rules and drive safely and will not change the lane rudely by considering the road constraints.

The vehicle with the P value closer to one will apply hard brakes and go for a lane change without considering road constraints. The second type of driver is enabled with L-IDM model (limited-IDM). This L-IDM is basically a crash free. The problem with L-IDM is it does not consider the P parameter which results in all vehicles in simulation will have same speed and the same driver behavior which is practically not realistic. IDM and network parameters used in simulations are specified in table 2.

Table 2: IDM and network parameters used in simulations

Parameters	Values	Units
b_{max}	[5.9, 8.4]	m/s^2
V^{des}	$V^{!}$ [0.80, 1.10]	m/s
A	1.7	m/s^2
B	1.4	m/s^2
T	[0.1, 1.1]	s
S_0	2	m
Δ	4	----
P	[0.0, 1.0]	#
b_{safe}	7	m/s^2
S_{min}	2	m
Data rate	6	Mbps
Bandwidth	10	Hz

VII. SIMULATION RESULTS

The figure 2 shows the graph plotted on EEBL vs EEBR based on distances between current vehicle and its front vehicle. The red colour line indicates EEBL system implemented vehicles when they come to complete stop the distance of the vehicles with respect to its front vehicle. The green colour line indicates EEBR system implemented vehicles when they come to complete stop the distance of the vehicles with respect to its front vehicle. The vehicle ID is represented by X-axis and y-axis represents distance in metres.

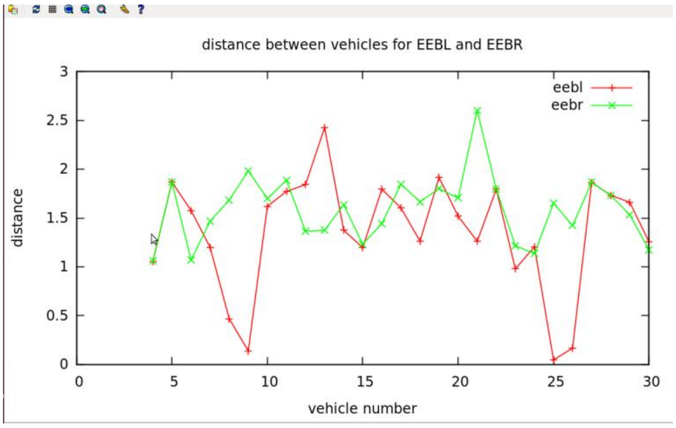

Fig 2: distance between vehicles of EEBL vs EEBR

The figure 3 shows the graph plotted on EEBL vs EEBR vs EEBA based on distances between current vehicle and its front vehicle. The red colour line indicates EEBL system implemented vehicles when they come to complete stop the distance of the vehicles with respect to its front vehicle. The green colour line indicates EEBA system implemented vehicles when they come to complete stop the distance of the vehicles with respect to its front vehicle. The blue colour line indicates EEBR system implemented vehicles when they come to complete stop the distance of the vehicles with respect to its front vehicle. The blue line in the graph is right above the green line as the vehicle stopping system is same in both in EEBA and EEBR. The vehicle ID is represented by X-axis and y-axis represents distance in metre

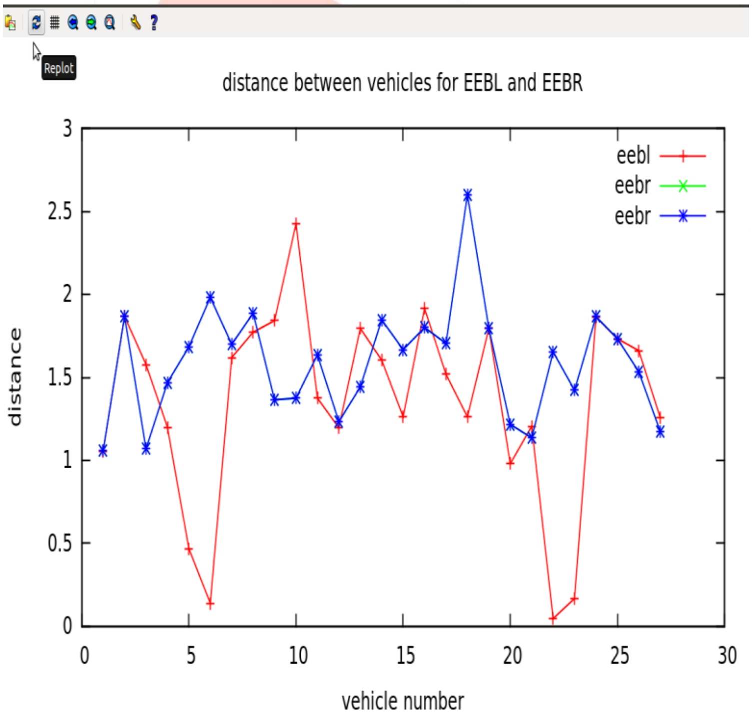

Fig 3: Distances between vehicles EEBL vs. EEBR vs. EEBA

The figure 4 shows the graphs plotted on EEBL vs EEBR on percentage of messages lost in each protocol. The vehicles on road move in high speed and when the leading vehicle applies hard brake it generates the message packet. The message packets are received by following vehicles and processed it. There is chance of messages broadcasted being lost. The graph shows percentage of message lost for EEBL and EEBR protocols. The green colour represents EEBL and blue colour line represents EEBR. The x-axis represents time in ms/10000 and Y-axis represents percentage of messages lost.

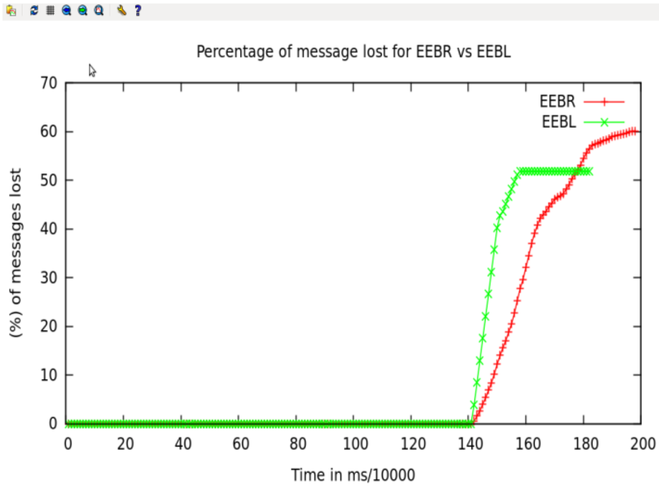

Fig 4: Percentage of message lost in EEBL vs. EEBR

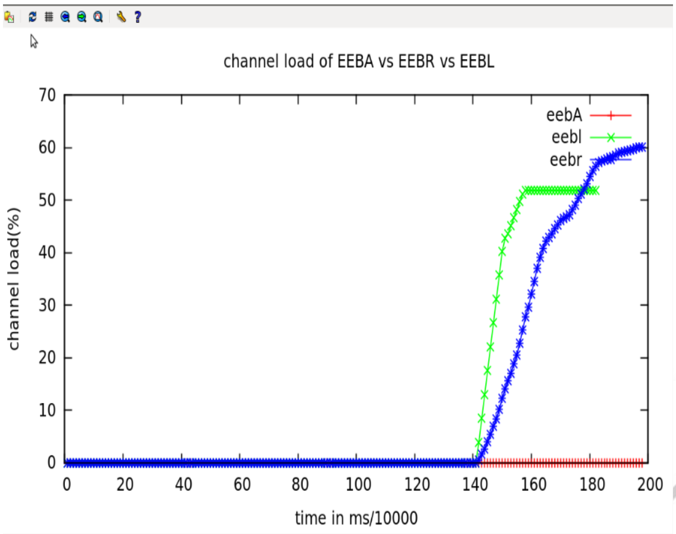

Fig 5: Percentage of message lost in EEBL vs EEBR vs EEBA

The figure 5 shows the graphs plotted on EEBL vs EEBR vs EEBA on percentage of messages lost in each protocol. The vehicles on road move in high speed and when the leading vehicle applies hard brake it generates the message packet. The message packets are received by following vehicles and processed it. There is chance of messages broadcasted being lost. The graph shows percentage of message lost for EEBL, EEBA and EEBR protocols. The red colour line represents EEBA, green colour represents EEBL and blue colour line represents EEBR. The x-axis represents time in ms/10000 and Y-axis represents percentage of messages lost

VIII. CONCLUSION

An automatic braking system is a mandatory component for ACC and cooperative driving in general. The vehicles on highway move at high speed. The scope for accident is very high due to hard brake on highways. The automatic braking system with EEBR and EEBA protocols will completely automate the braking system of vehicles if the vehicle's driver doesn't brake within safety time and safe distance. The proposed method will stop processing multiple copies of single brake message. The EEBA and EEBR are better when compared to EEBL in terms of crash probability and distances between vehicles when they come to complete stop on highway. The EEBA protocol is better when compared to EEBR and EEBL with respect to percentage of messages lost. They stress the need for proper message aggregation strategies to avoid clogging the network in the case of high vehicular density. The aggregation technique is best for its extreme simplicity and effectiveness, being able to reach an excellent compromise between network utilization and provided safety.

The work carried out is basically aimed for the highway scenario. Further work may include developing the ABS to more complex scenarios like city/town roads to avoid accidents in city/town zones with intersecting roads and traffic signals and the refinement of channel model.

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