CHAPTER 3

ENHANCED MULTICAST ALGORITHM FOR MOBILE ADHOC USING COOPERATIVE ADHOC MAC IN VANET

3.1 INTRODUCTION

In VANET, the communication, involving V2V and vehicle to RSU, is interrupted because of the unique features like high dynamic topology and predictable mobility. In contrast, Cooperative communication can considerably improve the consistency of the communication links in functioning of VANETs, mitigating the wireless channel harms as a result of the user mobility. In this chapter, cooperative scheme for medium access control (MAC), referred to as Cooperative ADHOC MAC (CAH-MAC), is proposed.

In the case of CAH-MAC, all the adjacent nodes work together by means of making the most of unreserved time slots for the purpose of resending of a packet which is unsuccessful to arrive at the objective receiver because of a reduced channel condition. However, even with these improvements, VANETs still have problems with traffic contention, namely hidden terminals, data transmission delays, decreasing throughput, and dynamic assigned channels for MAC protocols.
The proposed CAH-MAC protocol and the Enhanced Multicast Routing Algorithm (EMA) are employed for the betterment of the system. The multicasting routing protocols pose several challenges described in the subsequent section.

Scarce bandwidth of ad hoc networks, rapidly moving nodes with limited resources (battery power, memory usage), hidden terminal problem and security concerns remain a great challenge in designing multicast protocols. In addition, there are many more issues to be considered, but not limited to robustness (link stability), efficiency (ratio of overall quantity of data packets received to the overall number of packets (data and control) transmitted in the network,) control overhead (control packets exchanged), Quality of service (throughput, delay, delay jitter, and reliability), dependency on unicast routing protocol and resource management (battery power, memory).

3.2 SYSTEM MODEL

The proposed Enhanced Multicast Algorithm (EMA) uses cooperative MAC and the main intention of the multicasting routing protocol is to considerably diminish the number of packet retransmissions in VANET. The unreserved time slots are employed for the purpose of the retransmission of packets, when it fails due to poor channel condition. The proposed system model is explained below:

3.2.1 Network Topology and Channel Model

A VANET includes vehicles moving along the multi-lane road is considered. Vehicles are moving in an arbitrary method. Consider L is the amount of lanes, with the width \( w_l, l \in \{1, 2, 3, \ldots, L\} \). The entire vehicles move with slight relative movements in a particular observation time period.
So, they are stationary and relating to each other, keeping up a stable network topology as revealed in the Figure 3.1. It is impossible to differentiate all the Vehicles concerning their communication potentials with transmission range \( r \).

Vehicles within the transmission limit of a source node can effectively obtain the sent packets with the probability \( p \), considering a feasible poor channel condition. The probability \( p \) is completely based on the channel features. If the \( p \) value is smaller, the channel quality will be poorer. The parameter \( p \) does not consider transmission faults because of the collision, in case multiple nodes are inside interference ranges transmit concurrently.

\[
\text{Figure 3.1 Illustration of a two-hop set, where an ellipse stands for an OHS in order that the entire nodes within one ellipse can directly communicate with the remaining nodes, with node A as a reference.}
\]

Every vehicle holds back a record of its one-hop and two-hop neighbors and all these nodes can arrive at the destination at the most one and two hops of transmission in the same way from a reference node. Collections of nodes are One-Hop Set (OHS) and Two-Hop Set (THS), correspondingly. Node A is a constituent of two OHSs, namely, OHS 1 and OHS 2. Moreover it is a component of two-hop set, THS 1. It can communicate openly with several nodes in the OHSs. In the same way, the entire nodes in the similar THS can effectively keep in touch with each other with utmost two hops.
3.2.2 Channel Access

The channel access process completely depends on the distributed TDMA approach, in order that the channel time is completely partitioned into frames and every frame is then divided into time slots. Every time slot includes a stable time interval, and every frame includes a predetermined amount of time slots, indicated by F. Every vehicle has the adequate potential to sense the beginning time of a particular frame and, accordingly, the beginning time of a particular time slot.

Accessing a time slot consequently insists accurate time synchronization in the midst of nodes. In the scenario where a vehicle is equipped with a GPS receiver, the One-Pulse-Per-Second (1PPS) signal a GPS receiver obtains every second can be utilized for the purpose of synchronization. In case the GPS signal is lost, the GPS receiver’s local oscillator can be effectively utilized for a small time period and a distributed synchronization scheme, in case of a longer time period to synchronize nodes that support all modes of communication.

Nodes generate clusters of two-hop neighbors and at this point, a cluster indicates that a collection of nodes are at utmost two-hop transmission distance from one another. Here, there is no Cluster Head (CH), and a node itself can be a component of multiple clusters. Configuration of a THS avoids simultaneous utilization of a time slot through excess of one node inside the similar interference limit, and as a result, keeps away from the hidden node complication. Nodes which come under the identical THS compete with each other to hold back a time slot.

For a particular time slot, a node initially pays attention to the channel over the period of F successive time slots, subsequently attempting to reserve one time slot in the midst of the unreserved ones, if available. Access
collisions take place, when multiple nodes inside the same interference limit try to hold back that particular time slot. Subsequent to effectively holding back a time slot, a node sends a packet in the individual time slot in each frame still it meets a merging collision because of the relative mobility. Merging collision happens, when nodes with the similar time slot however belonging to various clusters move toward each other, ending in a transmission collision in the resultant time slot. It is to be observed that ADHOC MAC undergoes throughput reduction because of node mobility.

3.3 PROPOSED ENHANCED MULTICAST ALGORITHM FOR MOBILE ADHOC USING COOPERATIVE ADHOC MAC IN VANET TO IMPROVE THROUGHOUT PERFORMANCE

In order to overcome the throughput reduction, EMAC is proposed in this work, concentrating on cooperation to enhance the transmission reliability, and considering a network in which the entire nodes are completely synchronized, having reserved their time slots. Hence, access collisions do not occur and cooperation is carried out by only those nodes with their individual slots for the purpose of effective transmission. Furthermore, as relative mobility among nodes is negligible, the merging collisions do not occur; hence a reserved time slot is always dedicated to its owner.

In a particular frame, every time slot is under one of the following conditions: i) Reserved: Time slots are reserved when the data packets are successfully transmitted to the destination and considered as successful time slots. ii) Unreserved: Time slots not reserved until now by any node are unreserved time slots. iii) Failed: Slots other than an unreserved and successful slot are the failed time slots.
Because of the dynamic topology nature of VANET, the MAC protocols possibly will cause the wastage of time slots that occur when enough nodes are not there in a neighborhood to utilize the entire time slots of a frame. Additionally, in case of a transmission breakdown, the source node has to stay, in anticipation of the subsequent frame for retransmission is available even when the channel is inactive at some point in the unreserved time slots.

In the proposed algorithm, the unreserved time slots are effectively utilized for the retransmission of the failed packets beginning from the source to target destination, using the cooperative communication which, in contrast, can considerably boost the reliability of the communication links in VANETs, consequently mitigating the wireless channel impairments caused by the user mobility.

3.3.1 CAH-MAC Protocol Description

Here, the operation of CAH-MAC protocol including cooperation decision, helper selection and dynamic time slot allocation are discussed.

A particular node in its individual time slot sends a packet which includes Frame Information (FI), cooperation header, packet header, payload data, and Cyclic Redundancy Check (CRC). Figure 3.2 illustrates the structure of a packet that a node transmits. The structure and purpose of the signaling fields are described, with the FI and Cooperation Header (COH).
Figure 3.2 Structure of a packet and a FI field in CAH-MAC, where φ indicates a null field

FI is a set of ID fields (IDFs) and the amount of IDFs in a particular FI field is the same as FrameF, i.e., the quantity of time slots for each frame. Every IDF is devoted to the equivalent time gap of a frame. Temporary (short) identifier which is completely shorter (1–2 bytes) compared to the range of a MAC address, possibly be utilized as an ID of a node. This kind of a small ID can be chosen arbitrarily by a node, and transformed, if there is a divergence. The use of this kind of short ID considerably lessens the volume of the FI in a particular packet, and consequently, lessens the overhead of MAC.

The destination node, D, upon getting a packet from the source node S in the $s^{th}$ time slot, confirms that the $s^{th}$ time slot is allocated to S. Node D subsequently places the ID of node S in the $s^{th}$ IDF of its FI. After successfully getting a packet from a particular node S, the node D is familiar with (a) the existence of node S as its one-hop neighbor, (b) node S indicates the owner of the $s^{th}$ time slot, and at last (c) the entire one-hop neighbors of node S and their related time slots.

Thus, by means of successfully receiving FIs from the entire one-hop neighbors. A node preserves a neighbor table which comprises:
(i) the entire one-hop neighbors, (ii) the entire two-hop neighbors, and (iii) the owner of every time slot in a particular frame. When there is no signal in a particular time slot, a node takes it as an unreserved time slot. In these scenarios, the related IDF of the unreserved time slots are unfilled in FI as given in Figure 3.2.

All nodes can recognize an unreserved time slot where it can send without generating further collision in its one-hop neighborhood. It is to be observed that a particular node revises its neighbor-table in accordance with any packets obtained effectively from the new neighbors. All these packets can be of any type, i.e., broadcast, unicast, or multicast packets. Besides, the neighborhood detection, configuration of a THS cluster, and reservation of time slot, the FI also assists in transmission acknowledgement. For instance, take node D does not comprise the ID of node S in the IDF-S of the FI. After getting FI from D, the node S concludes a transmission breakdown between itself and D in the s\textsuperscript{th} time slot, that is fundamentally a negative acknowledgement (NACK). In the same way, insertion of the node S ID in the FI of node D serves as acknowledgement of a completed transmission from S to D.

3.3.2 Cooperation among Neighboring Nodes

Cooperation is constantly carried out all the way through a one-hop neighbor of the source and destination nodes. Given that the channel condition possibly will constant throughout the idle time slot, as that at some point in the source node’s time slot, the resending through the source node throughout the vacant time slot is not expected to be useful and will ravage the transmission opportunity.

In contrast, cooperative relay transmission of a packet, by means of an independent channel (i.e., among the helper and destination) throughout an
unreserved time slot, offers the transmission diversity, and so, enhances the transmission reliability even when the channel condition between an s–d pair is poor. At this point, the node makes a decision and executes cooperation. Consider $F = \{1, 2, 3, \ldots, F\}$ indicates the collection of time slots in a frame. Let $O_x$ and $T_x$ stands for the OHS and THS of a particular node $x$. Consider $R_x$ represents a collection of the entire time slots which comes under the THS of node $x$, i.e., any time slot $t \in R_x$ is reserved from the viewpoint of node $x$. Assume $S$ and $D$ as the source and destination nodes with the $s^{th}$ and $d^{th}$ time slots correspondingly, and node $H$ as the helper node. The Cooperation decision and cooperative relay transmission are carried out only when the entire following stipulations are met.

1. The direct transmission fails: Cooperation is activated, in case the direct transmission between the source and the destination fails. Upon a transmission breakdown, the node $D$ will not confirm the transmission from the node $S$, so that $S/\in O_D$. Potential helper nodes have the transmission breakdown information, following the process of receiving the FI from node $D$.

2. The helper effectively obtains a packet for retransmission: A node can potentially provide cooperation, only when it obtains the packet effectively from the source node $S$ at some point in the $s^{th}$ time slot.

3. There is an available time slot: Helper node $H$, when these three stipulations are met, can offer and execute cooperation when there exists no less than one unreserved time slot $h \in F$ at some point where it can be sent. The transmission from $H$ in a particular time slot $h$ shall not route for any collision at its one-hop neighbors, i.e. $\forall h \notin RH$. 
When all the previous stipulations are met, the helper node $H$ provides cooperation with the source and destination and the cooperative transmission is completed in a particular time slot $h$. When there are numerous potential helper nodes, the particular one that initially announces to assist will effectively relay the packet, at the same time the remaining potential helpers will not continue with cooperation for the particular packet.

Figure 3.3 shows the necessary details exchanged for the purpose of cooperation in the CAH-MAC. If the destination node $D$ is unsuccessful in obtaining a packet from the particular sender node $S$ as in Figure 3.3(a), it declares the transmission breakdown through its FI as shown in Figure 3.3(b). Upon making a decision to cooperate, the helper node $H$ sends its cooperation by means of cooperation header (COH) as in Figure 3.3(c).

During the $h^{th}$ time slot, subsequent to receiving a cooperation acknowledgement (C-ACK) from the particular destination node $D$, the helper node $H$ sends the packet that node $D$ has failed to obtain as in Figure 3.3(d). Subsequently, the COH is discussed wherein $H$ offers cooperation correspondingly, C-ACK is explained wherein a destination node is used for the purpose of avoiding collision during the cooperative relay transmission.

![Figure 3.3 (a) Source node sends a packet to the specific destination](image-url)
Figure 3.3(b) Neighboring nodes detect transmission failure following the process of examining the FI from the destination.

Figure 3.3 (c) Helper node H, effectively provides cooperation.

Figure 3.3(d) Helper node H, re-transmits the packet that failed to reach the destination, after getting a cooperation acknowledgement from the particular destination.

Figure 3.3 Information exchanges in the CAH-MAC.
When a node makes a decision to work together, it sends its decision through cooperation header in its packet. The following points are to be incorporated within the cooperation header:

- Its objective to cooperate,
- The index of the time slot of the source at some point where the transmission breakdown has occurred
- The index of the chosen unreserved time slot wherein the packet will be resent from the H to the destination.

The above mentioned details are embedded in the cooperation header and sent to the helper’s time slot. The remaining potential helpers (that can provide cooperation and are in the OHS of helper node) terminate their intentions, once they obtain cooperation decision from the H. Thus, the helper node H is the one that initially provides cooperation, and executes cooperation for the S – D pair. This kind of suspension of cooperation intention keeps away from collision among the potential helpers throughout the cooperative relay transmission.

In contrast, collisions possibly will take place at the destination node, when two or more potential helpers, which are not in each other’s OHS, provide cooperation at the same unreserved time slot. With the aim of keeping away from these collisions, a C-ACK from the destination node is sent during the chosen unreserved time slot, as shown in Figure 3.4. In C-ACK, the destination node places the ID of the primary potential helper that provided cooperation. Transmission of a C-ACK from the destination node pulls the remaining potential helpers in order to delay their transmissions, avoiding any likely collision. The helper node resends the packet that has failed to arrive at the destination in the direct transmission from the source node.
The size of a short ID is sufficient to be distributed along with the nodes that share a particular frame. For this reason, the size of an index of a particular time slot is equivalent with the size of a short ID. Accordingly, the size of a cooperation header is small compared to the size of FI, which has a room for F IDs. In general, the F value is fixed as large and adequate to assure a time slot for every node. Additionally, the C-ACK and the cooperative transmission are carried out in an unreserved time slot. Therefore, cooperation can be carried out at the cost of slight overhead as compared to a particular time slot which would be misused in case of lack of cooperation. It is to be observed that, only one helper in the proposed CAH-MAC executes the cooperative relay transmission for an unsuccessful S – D direct transmission. Potential helpers, which can provide cooperation to the unsuccessful S – D direct transmission, terminate their cooperation intentions once they obtain cooperation decision from the helper node. Therefore, a potential helper provides cooperation to only those unsuccessful S – D direct transmissions which are not provided with cooperation, however not to all failed S – D direct transmission. This considerably lessens the size of COH and therefore the communication overhead because of cooperation.

Figure 3.4  Cooperative relay transmissions during an unreserved time slot
The transmission of C-ACK signal from the destination node forces the other potential helper nodes to terminate their transmissions, keeping away from any possible collision. The collision avoidance process is discussed below.

3.3.3 Cooperation Collision Avoidance

CAH-MAC experiences the complication of cooperation collisions, when the reservation packets from a new node have a collision with C-ACK from the destination node and/or payload data from the helper node. The easiest technique to keep away from cooperation collisions is to delay the cooperative relay transmission with some time interval, say $\alpha_1$ time units. The period of $\alpha_1$ must be adequately long enough for a node to recognize whether the channel is inactive or full of activity, such as the Distributed Inter-Frame Space (DIFS) as in the IEEE 802.11 based MAC protocols. Destination node D stays for $\alpha_1$ time units and sends C-ACK when the channel is inactive during the waited time (i.e., when there is no transmission in that unreserved time slot), which is demonstrated in Figure 3.4. Let it to be observed that in CAH-MAC, the destination node sends C-ACK once the unreserved time slot begins, i.e., $\alpha_1 = 0$. The helper node, subsequent to receiving its ID in the C-ACK from the destination node, sends a payload data from the source following a guard time. In view of the fact that the length of C-ACK (in bits) and guard time are stable, the helper node constantly performs cooperative relay transmission, after the predetermined duration from the start of a time slot, i.e., $\alpha = \alpha_1 + \alpha_2$ time units as shown in Figure 3.4, which $\alpha_2$ indicates the transmission time of a C-ACK in addition to the guard time.

A new node makes an attempt to hold back the unreserved time slot by sending a packet in the same time slot. If the destination node senses the
reservation packet(s) from the new node(s), it terminates the cooperation or transmission of the C-ACK. At the same time, as the helper node does not obtain any C-ACK, it also terminates cooperative relay transmission following $\alpha$ time units, from the start of a time slot. Delaying the cooperative relay transmission phase permits the destination node to sense the reservation packet from a new node and stay away from a collision among C-ACK and the reservation packet.

This kind of collision takes place only when a new node and the destination node are in each others’ two-hop distance however not in the one-hop distance. In such a scenario, the destination node does not recognize the transmission of the reservation packet from the new node and sends C-ACK. Collisions take place, when there is a concurrent transmission from the destination and new nodes, at their standard one-hop nodes.

It should be observed that a helper node does not send the FI at some point in the cooperative relay transmission, i.e., the packet from a helper node includes the Packet Header (PH), payload data and CRC only. Since each node has its individual time slot wherein it sends a complete packet, reiterated transmission of the FI at some point in cooperative relay transmission can be circumvented. The non existence of FI balances the delay time of the cooperative relay transmission phase, and does not have an effect on the normal operations of CAH-MAC. Besides, the new nodes send reservation packets without cooperation header as they are not appropriate to carry out cooperation.

In that scenario, a collection of new features are proposed both in the data and control plane of the 802.11 MAC layers, at the same time, maintaining the backward compatibility to the existing MAC. The most important constituent of Cooperative MAC control plane design is the method for every station for the purpose of learning the subject of candidate helper
stations, subsequently the related data structures utilized to accumulate the information connected to those recognized candidates. In case of the data plane, a station can decide a H from the provided list of potential H to utilize during the time of its transmissions, based on the prospect of dropping the transmission time for the packet available.

3.4 COOPERATIVE MEDIUM ACCESS CONTROL

In this section, the learning process and the related data structure are described, and then, the cooperative operation in the data plane is explained in detail.

Every RSU in a Basic Service Set (BSS) should keep a table, of potential helpers indicated as the Cooperative Table, that can be utilized for support during the transmission between the vehicle to vehicle or vehicle to RSU. The formation and updating of the cooperative table for every probable destination address can be processed by listening to the on-going transmission. Since every station in 802.11 networks is needed to test out the packet header of the entire packets so that it may receive the packets intended for it, this condition does not necessitate any additional hardware.

All these stations are also essential for decoding the complete Request-To-Send (RTS), Clear-To-Send (CTS) and Acknowledgment (ACK) frames for the purpose of obtaining the channel reservation details to keep away from the hidden node complication. The control frames and the headers of the data frames are continuously modulated on the base rate, in order that the entire stations inside the transmission limit may be capable of receiving this information productively and efficiently.

In case a transmission from a station $S_h$ is overheard, a CoopMAC station $S_s$ approximates the channel condition (e.g. path loss) among the
correspondent of that packet and itself through computing the received signal strength. In view of the fact that the entire stations make use of the similar frequency band for the purpose of transmission and reception, the channel between any two particular stations is presumed to be symmetric. The path loss is computed through the process of subtracting the transmission power, which is in general predetermined for the entire stations, from the received signal power.

The accessibility of this information is maintained by the IEEE 802 Protocol. By means of examining the threshold value, that is pre-computed and assured a definite bit error rate for every modulation scheme, it can discover the related data rate among $S_h$ and $S_s$, indicated by $R_{sh}$. If station $S_s$ overhears a data packet transmission among a pair of remaining stations (from $S_h$ to $S_d$), it will recognize the data rate employed for this transmission from the Physical Layer Convergence Procedure (PLCP) header. This rate is indicated as $R_{hd}$.

<table>
<thead>
<tr>
<th>ID (48 bits)</th>
<th>Time (8 bits)</th>
<th>$R_{hd}$ (8 bits)</th>
<th>$R_{sd}$ (8 bits)</th>
<th>Number of Failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAC address of helper 1</td>
<td>Time the last packet heard from helper 1</td>
<td>Transmission rate between helper 1 and the destination</td>
<td>Transmission rate between the source and the helper1</td>
<td>Count of Sequential transmission failures</td>
</tr>
<tr>
<td>MAC address of helper 2</td>
<td>Time the last packet heard from helper 2</td>
<td>Transmission rate between helper 2 and the destination</td>
<td>Transmission rate between the source and the helper2</td>
<td>Count of Sequential transmission failures</td>
</tr>
<tr>
<td>……</td>
<td>……</td>
<td>……</td>
<td>……</td>
<td>……</td>
</tr>
<tr>
<td>MAC address of helper N</td>
<td>Time the last packet heard from helper N</td>
<td>Transmission rate between helper N and the destination</td>
<td>Transmission rate between the source and the helper N</td>
<td>Count of Sequential transmission failures</td>
</tr>
</tbody>
</table>

**Figure 3.5 Format of the cooperative table**
The fields included in the Cooperative Table are revealed in Figure 3.5. Entries are arranged through the timestamp values, in accordance with the last time a packet from that station is overheard. A helper station is accumulated in the Cooperative Table by \( S_s \) when it satisfies,

\[
\frac{1}{R_{sh}} + \frac{1}{R_{hd}} > \frac{1}{R_{sd}}
\]  

(3.1)

where \( R_{sd} \) indicates the rate for the purpose of direct transmission among \( S_s \) and \( S_d \). The initial column is, specifically the ID field that accumulates the MAC address of the potential Helper nodes learned from the RTS frames transmitted by the helper. Time field accumulates the specific time of the very last frame transmission obtained from this helper. As described above, \( R_{hd} \) and \( R_{sh} \) accumulate the data rate from the helper station to the destination \( S_d \), and from the source \( S_s \) to the helper station, correspondingly. The final field in the table, number of failures tracks the quantity of sequential failures related with the specific helper station. If this number goes beyond predetermined threshold values, which recommended being in the proposed protocol, the related entry is eliminated from the Cooperative Table. The value of NumOfFailures is incremented subsequent to every failed transmission attempt. Each of these entries is revised to replicate the current channel situations and position. Cooperative Table entries can also be populated by means of information acquired from cooperative transmissions received by a station.

3.4.1 Transmission Algorithm

If a source station \( S_s \) has the data of length \( L \) octets to transmit, it checks every entry in the Cooperative Table to make a decision whether to send through a specific helper. The transmission time for these two hop transmission is \( 8L/R_{sh} + 8L/R_{hd} \), paying no attention to the overhead. The
helper from which the least amount of transmission time can be realized will be selected as the candidate helper. When multiple stations comprise the similar value, decide the one with the most current time value is decided.

The same as in the available standard, the mode selection entirely depends on a configurable RTS threshold. In case the packet length is larger than this particular threshold, the RTS/CTS mode is preferred. When transmission through the preferred helper is extremely efficient then a direct transmission, will begin a cooperative transmission. In case of the RTS/CTS mode, the stipulation for a cooperative transmission can be given as follows

\[
\frac{8L}{R_{sh}} + \frac{8L}{R_{hd}} + T_{PLCP} + T_{HTS} + 2T_{SIFS} < \frac{8L}{R_{direct}} \tag{3.2}
\]

where \(R_{direct}\) stands for the steady data rate for a direct transmission from \(S_s\) to the destination \(S_d\) and \(T_{PLCP}, T_{HTS}\) and \(T_{SIFS}\) are the extra time related with a helper-assisted transmission for the physical layer overhead, HTS and SIFS, correspondingly.

In case the base mode, in which the data packets are not headed by RTS/CTS, the order is given as,

\[
\frac{8L}{R_{sh}} + \frac{8L}{R_{hd}} + T_{PLCP} + T_{SIFS} < \frac{8L}{R_{direct}} \tag{3.3}
\]

In case if the condition is not met for all the entries in the Cooperative Table, the data frame is transmitted directly to \(S_d\) as discussed in Algorithm 1.
Algorithm 1:

A source station $S_s$ has data of a length $L$ octets to transmit the transmission for such a two hop transmission is $\frac{8L}{R_{sh}} + \frac{8L}{R_{hd}}$.

Step 1: When multiple stations have the equivalent value,

Step 2: The one with the most current Time value Source station $S_s$ is preferred.

Step 3: The duration field in the Cooperative RTS is specified by

$$\text{Duration Cooperative RTS} = 4\text{TSIFS} + \text{TCTS} + \frac{8L}{R_{\text{direct}}} + \text{TPLCP} + \text{TACK Helper station}S_h.$$  

Where $S_h$ receives a Cooperative RTS message, $S_h$ should verify conditions of the rate $R_{S_h}$ between itself and $S_s$,

$S_d$ recommended in the Cooperative RTS messages are sustainable Destination station $S_d$:

if $S_d$ receives a Coop RTS, whose RA fields is fixed to the MAC address of $S_d$.

3.4.2 Coop MAC - RTS/CTS Mode

The RTS/CTS mode given by 802.11 is expanded to comprise a Helper ready To Send (HTS) for the purpose of helper station to effectively acknowledge its involvement. The HTS packet posses the identical format as CTS in the 802.11 standard, and consequently, the legacy stations can effectively decode this packet. Source station $S_s$ chooses one of the potential helpers $S_h$ from the Cooperative Table, and indicates the helper in the modified Cooperative RTS message. The frame format for Cooperative RTS message is depicted in Figure 3.6 (a) also the frame format for MAC Header and Control Header for 802.11 is shown in Figure 3.6 (b) and Figure 3.6 (c)
respectively. The swap over of control messages in Cooperative MAC and the related NAV settings are explained in Liu et al (2007).

3.4.3 Cooperative MAC - Data Transmission

Every Cooperative MAC station is supposed to be capable of differentiating whether a packet is for itself or to be sent to some other station. In the case of a RTS/CTS defended data transmission, every station is capable of doing so. On the other hand, in the base mode operation of 802.11 MAC, Cooperative MAC permits the nodes to send a data frame openly to the potential helper nodes without passing through the RTS/CTS procedure. Accordingly, a unique Cooperative MAC data frame is required.

The Address 4 field in the IEEE 802.11 frame arrangement is not at all utilized for data frames, but apart from the data frame is swapped
among APs, where the toDS and fromDS subfields inside the frame control field are both fixed to 1. At this point, the subsequent frame format is proposed for the purpose of data transmission together in the base mode and in the Cooperative RTS-HTS-CTS mode. In order to keep holds of the similar functionalities for toDS and fromDS at the same time exploiting the reserved data frame Subtype value of 1000 for Coop MAC data frames. During the initial hop, $S_S$ places the helper $S_h$ address in the Address 1 field of the MAC header and the destination address $S_d$ in Address 4. If the packet enters the helper, it will shift the address of $S_d$ in Address 4 to Address 1, recompute the Frame Check Sequence (FCS) and transmit the data frame to the ultimate destination $S_d$ following an SIFS interval. $S_d$ transmits an ACK message directly to $S_S$. In the scenario where an ACK message is not obtained by $S_S$, it have to increment the NumOfFailures and eliminate the potential helper station from its Cooperative Table, when NumOfFailures $> \text{Threshold}$.

It is to be noted that it is possible to readily extend the Cooperative MAC to the remaining higher data rate extensions of 802.11, although the current Cooperative MAC is assessed for IEEE 802.11b. Through investigation and simulation one can show that the energy-per-bit occurred through the helper stations is diminished through the process of participating in cooperation. This counter-intuitive effect is because of the considerable drop in idle energy consumption incurred by the helper, since it stays for its transmission opportunity, at the same time, a time-consuming node is engaging the channel. A preliminary execution of the cooperative transmission has been done and the experimental result from the implementation is given in the following section.
3.5 SIMULATION AND RESULTS

The simulations are completely based on the IEEE 802.11b of MAC layer included in the NS2. The vehicles move from a random starting point to a random destination along the road, here the speed is consistently distributed between 0 - 20 m/s. The transport protocol is User Datagram Protocol (UDP). Traffic sources are Constant-Bit Rate (CBR) and the source and destination pairs are randomly spread over the entire network. The packet generating rate is 4 CBR. The number of sources is 10 in the network. These scenario files are generated by the scene generator of the simulator. The mobility model is a random way point model in a rectangular field and the related parameters are shown in Table 3.1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topology area</td>
<td>1000m * 1000m</td>
</tr>
<tr>
<td>Simulation time</td>
<td>2,000 sec</td>
</tr>
<tr>
<td>Traffic type</td>
<td>CBR</td>
</tr>
<tr>
<td>CBR packet size</td>
<td>512 bytes</td>
</tr>
<tr>
<td>Mobility model</td>
<td>Random way point</td>
</tr>
<tr>
<td>Pause time</td>
<td>1 sec</td>
</tr>
<tr>
<td>Voltage</td>
<td>5V</td>
</tr>
</tbody>
</table>

Each node is primarily positioned at a random position inside the defined area, the throughput with the smallest amount of safety distance, $d_0$, among the nearby vehicles in a particular lane, and the investigative results with $d_0 = 0$. The better channel quality raises the probability of completed relay transmission, since the channel quality additionally represents the throughput increase of CAH-MAC over ADHOC MAC against the channel.
parameter $p$ for a variety of vehicle density values. At the same time as $p$ increases from 0.01 to 0.03, the throughput gain increases with $p$.

The throughput gain diminishes, when the amount of THS members is larger compared against $F$. In case of the parameter pair, it is observed that the throughput gain attains its highest point at a particular $p$ value, and begins decreasing as $p$ further increases with a Maximum $p$ value, the probability of completed direct transmissions raises, and therefore cooperation possibly will not be sparked. When $p$ reasonable, the direct transmission is possibly will suffer from the channel errors and therefore cooperation helps to resend the packet that failed to arrive at the destination.

3.5.1 Packet Drop Comparison

![Graph showing packet drop comparison](image)

**Figure 3.7 Comparison of packet drop for different protocols**

In Figure 3.7, the graphical representation of packet drop for the proposed enhanced multicast algorithm (EMA-CAH-MAC) protocol, and the existing protocols such as CAH-MAC and MAC are shown. It is observed that the EMA-CAH-MAC protocol has a lower packet drop value compared
with other techniques such as EMA-CAH-MAC, CAH-MAC and MAC. The usage of the unreserved time slots for the retransmission of the failed packets in the network is known. The helper nodes are used to allocate the unused time slots for sending the failed packets, reducing delay. Table 3.2 shows the experimental values of the proposed algorithm and the existing algorithms.

Table 3.2 Comparison of packet drop for different routing protocols

<table>
<thead>
<tr>
<th>Time (in ms)</th>
<th>Proposed EMA-CAH-MAC</th>
<th>CAH-MAC</th>
<th>MAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.2</td>
<td>0.5</td>
<td>0.75</td>
</tr>
<tr>
<td>1</td>
<td>0.26</td>
<td>0.53</td>
<td>0.78</td>
</tr>
<tr>
<td>2</td>
<td>0.28</td>
<td>0.56</td>
<td>0.81</td>
</tr>
<tr>
<td>3</td>
<td>0.32</td>
<td>0.59</td>
<td>0.83</td>
</tr>
<tr>
<td>4</td>
<td>0.34</td>
<td>0.62</td>
<td>0.86</td>
</tr>
<tr>
<td>5</td>
<td>0.36</td>
<td>0.66</td>
<td>0.87</td>
</tr>
<tr>
<td>6</td>
<td>0.38</td>
<td>0.69</td>
<td>0.89</td>
</tr>
</tbody>
</table>

Table 3.2 shows the packet drop values for different protocols such as EMA-CAH-MAC, CAH-MAC, and MAC. The simulation is carried out and the corresponding values are tabulated for the existing approaches such as CAH-MAC and MAC. The proposed EMA-CAH-MAC approach produces significant results with low packet delay value in spite of the time increment. The packet drop value of the proposed EMA-CAH-MAC for 5 milliseconds in the network is 0.36, which is lower than 88.95% of CAH-MAC and 75.48% of MAC approaches, respectively.

3.5.2 Packet Delivery Ratio

Figure 3.8, shows the graphical representation of the packet delivery ratio for the proposed enhanced multicast algorithm (EMA-CAH-MAC) protocol and the existing protocols such as CAH-MAC and MAC. It is
observed that the EMA-CAH-MAC protocol has a higher packet delivery ratio value compared with other techniques such as CAH-MAC and MAC.

Figure 3.8  Comparison of packet delivery ratio for different routing protocols

The usage of the unreserved time slots for the retransmission of the failed packets in network is the main reason for reducing delay and increasing packet delivery ratio. Table 3.3 shows the experimental values of the proposed algorithm and the existing algorithms.

Table 3.3  Comparison of packet delivery ratio for different routing protocols

<table>
<thead>
<tr>
<th>Number of nodes</th>
<th>Packet delivery ratio (in %)</th>
<th>Proposed EMA-CAH-MAC</th>
<th>CAH-MAC</th>
<th>MAC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>89</td>
<td>78</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>92</td>
<td>79</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>93</td>
<td>81</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>94</td>
<td>83</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>95</td>
<td>85</td>
<td>71</td>
<td></td>
</tr>
</tbody>
</table>
Table 3.3 shows the packet delivery ratio values for different protocols such as EMA-CAH-MAC, CAH-MAC and MAC. The simulation carried out, the corresponding values are tabulated for the existing approaches such as CAH-MAC and MAC. The proposed EMA-CAH-MAC approach produces significant results with high throughput value for increased time. The throughput value of the proposed EMA-CAH-MAC for 400 nodes in the network is higher than 27.65% of CAH-MAC and 11.70% of MAC approaches, respectively.

3.5.3 Throughput

Figure 3.9, shows the representation of the throughput for the proposed enhanced multicast algorithm (EMA-CAH-MAC) protocol and the existing protocols such as CAH-MAC and MAC. It is observed that the EMA-CAH-MAC protocol has a higher throughput value compared with other techniques such as CAH-MAC and MAC.

![Figure 3.9 Comparison of throughput for different routing protocols](image-url)
Table 3.4 shows the experimental values of the proposed algorithm and the existing algorithms.

**Table 3.4 Comparison of throughput for different routing protocols**

<table>
<thead>
<tr>
<th>Number of nodes</th>
<th>Proposed EMA-CAH-MAC</th>
<th>CAH-MAC</th>
<th>MAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.88</td>
<td>0.78</td>
<td>0.62</td>
</tr>
<tr>
<td>200</td>
<td>0.92</td>
<td>0.79</td>
<td>0.65</td>
</tr>
<tr>
<td>300</td>
<td>0.93</td>
<td>0.81</td>
<td>0.66</td>
</tr>
<tr>
<td>400</td>
<td>0.94</td>
<td>0.83</td>
<td>0.68</td>
</tr>
<tr>
<td>500</td>
<td>0.95</td>
<td>0.85</td>
<td>0.71</td>
</tr>
</tbody>
</table>

Table 3.4 shows the throughput values for different protocols such as EMA-CAH-MAC, CAH-MAC and MAC. The simulation has been carried out and the corresponding values are tabulated for the existing approaches such as CAH-MAC and MAC. The proposed EMA-CAH-MAC approach produces significant results with a higher throughput value for an increased time. The throughput value of the proposed EMA-CAH-MAC for 300 nodes in the network is higher than 29.03% of CAH-MAC and 12.90% of MAC approaches, respectively.

From the above results, it is evident that for a heavy traffic scenario such as the parking spot reservation, where there is high traffic on roads, the proposed EMA-CAH-MAC is highly suitable for multicasting operation. During heavy traffic, the message cannot be forwarded to all nodes in an efficient manner. As a result, either collision will occur or the rate of packet dropping will be high. The proposed EMA-CAH-MAC solves the problem, using the unused time slots for the retransmission of packets as, the packet delivery ratio, and the throughputs are high and packet delay is low.
3.6 CONCLUSION

The implementation of the Enhanced multicast algorithm (EMA-CAH-MAC) is discussed briefly which is used to reduce the delay shown by the vehicles as they pass through the intersection (RSU). Each and every node time slot is allocated, using the process of discrete TDMA process in this proposed approach. The major advantage of the proposed scheme is that considerably enhances the packet delivery ratio in a dynamic topology of VANET. Network lifetime is accomplished by finding multicast path that tends to minimize the variation of the remaining energy of all the nodes and increase the throughput using header table.

Numerical results make it obvious that throughput gain by cooperation is substantial for a moderate channel circumstance. Besides, the throughput gain is substantial in the existence of a reasonable quantity of nodes in a two-hop neighborhood compared against the overall quantity of time slots available in a frame.

The performance of the proposed (Kamalavathi & Radhakrishnan 2015(b)) technique is validated and characterized by comparing it with the performance of the existing MAC.