Chapter 4

The proposed approach

Broadcast communication is the preferred method of disseminating safety-related data in the VANET. In fact, non-safety-related applications also use broadcast as part of data routing [26]. In the context of VANET, broadcast storms and network congestion are the most serious challenges due to high mobility and specific VANET characteristics. This challenge motivates this thesis to propose a reliable and efficient safety-related data dissemination protocol.

We investigated the broadcast storm and network congestion issues as part of our research efforts for the vehicle-to-vehicle (V2V) communication protocol for safety message dissemination. Most of the existing solutions use greedy forwarding-based data dissemination, which attempts to increase delay performance and mitigate the broadcast storm issue. But it doesn't take into account scalability and reliability, which are very important in large VANET networks.

4.1 Overview

In our proposed approach, we are aiming at achieving three main objectives: scalability, reliability, and delay efficiency.

To achieve scalability, we address the broadcast storm problem in large-scale scenarios, such as high-density traffic regimes. The scalability at large scale vanet scenarios is achieved by efficient redundancy reduction method. The reliability of the protocol is achieved by using current signal characteristics along with other parameters. A reduction in congestion-induced packet drops improves the delay characteristics of the protocol.

Initially, we simulated delay-based greedy data dissemination schemes, which is the simple farthest-distance-based scheme. It forms the foundation for further improvements in terms of increased reliability and scalability. It efficiently reduces message redundancy and mitigates broadcast storm problems, but it induces more delay due to non-adaptive delay characteristics. High delay and high network density deteriorate the overall performance of the protocol.

Later, the delay-adaptive protocol's performance is enhanced by a more sophisticated delay-based technique. We named it the "efficient and reliable data broadcast protocol"(ERDB). ERDB dynamically estimates the actual transmission range and instantaneous channel characteristics to improve delay performance and reliability.

4.2 Models

Due to its high cost and complexity, the development of a VANET environment for testing and research purposes is not practically feasible. As a result, the majority of VANET research is conducted solely in a simulation environment [16]. Standard simulation tools, simulation parameters, and realistic mobility models are required to produce an acceptable and realistic VANET simulation system.

VANET simulation is made up of three different modules: road layout, communication, and mobility models. For road topology, we used a straight, multi-lane highway, and a realistic urban road scenario. Urban scenarios can be as well-structured as sectorial road networks or as random as the road networks found in old cities. Realistic traffic or vehicular mobility is generated over these road networks through the use of SUMO [30][8].

We adopt the IEEE 802.11p standard, which is a standard for wireless communications in a vehicular environment. The proposed data dissemination protocol works above the MAC layer[5]. The assumed VANET architecture is presented in figure 4.1, where each vehicle is equipped with On-Board-Unit(OBUs) and Road Infrastructure is equipped with Road-Side-Unit (RSUs). However presented protocol works without the need of V2I communication mode [18] [51].

An OBU is a smart embedded device with an IEEE 802.11p-based radio device. It also has a processor, memory, storage, and user interface for handling ITS

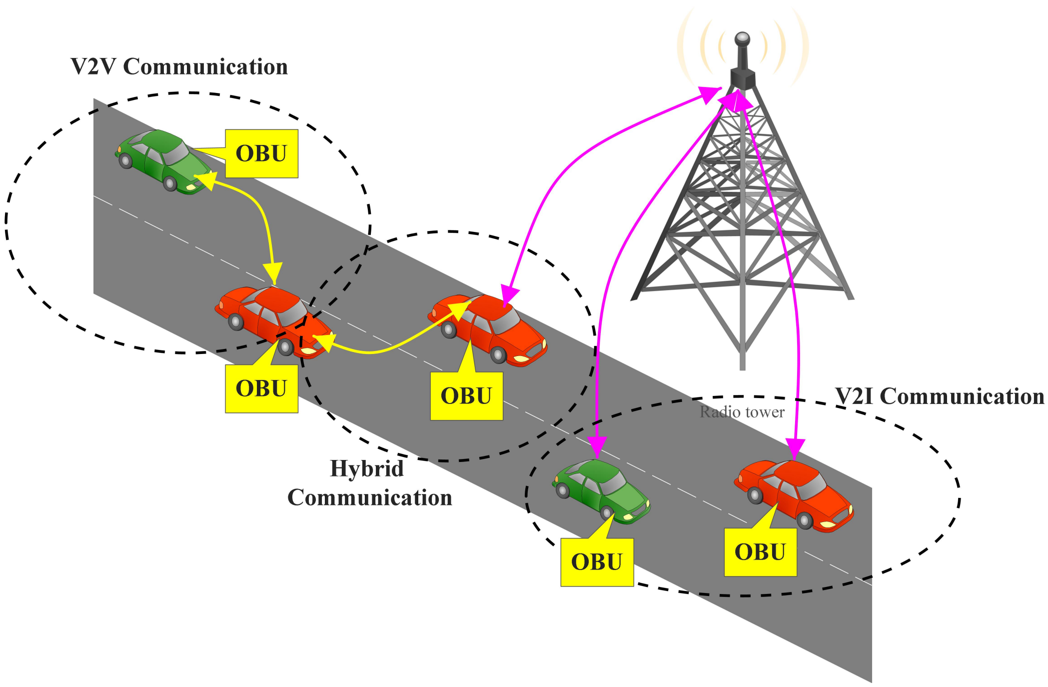

Figure 4.1: VANET environment

applications. With the use of OBUs, vehicles communicate with each other wirelessly. They are also able to interact with roadside units (RSUs). This research work only focuses on vehicle-to-vehicle (V2V) capabilities due to the high cost of RSU infrastructure developments.

Wireless access in vehicular environments (WAVE), as described in the section 2.4.2, specifies the format of messages used in vehicular networks. These messages are called wave short messages (WSMs). Through the exchange of WSMs, vehicles are sharing crucial information, such as ID, location, speed, route, etc., with other vehicles.

Mainly, two types of messages called beacon(WSMs) and alert messages are used. (i) Beacon messages are periodic messages exchanged between vehicles to share the most recent vehicle states. It includes information such as vehicle ID, message ID, and location information. When a vehicle detects an emergency, it generates and transmits alert messages to notify other vehicles in the area of the emergency [4]. Alert messages follow multi-hop communication over a larger

Field	**Description**
S_{id}	Source Identifier
M_{id}	Message Identifier
P_s	Source Coordinates
MR	Transmission Range
t	Timestamp

Table 4.1: Beacon message format

distance beyond the scope of single-hop transmission. The decision to select next relay vehicle for multi-hop communication is taken by using different schemes described in chapter-3. Table-4.1 & 4.2 show the detailed parameters of beacon and alert messages, respectively.

Field	**Description**
S_{id}	Alert Generator Identifier
F_{id}	Alert Forwarder Identifier
M_{id}	Message Identifier
P_s	Alert Source Coordinates
P_f	Alert Forwarder Coordinates
MR	Transmission Range
H	Hop-count
t	Timestamp

Table 4.2: Alert message format

The maximum size of a packet that is allowed through 802.11p-based communication is 2312 bytes. Here, packet size is considered 200 bytes to accommodate all crucial information in beacons as well as alert messages. In the following, we define each message parameter.

- **Source Identifier (V_{id}):** The Source ID is a unique number for the vehicle that originally created the message. It is also known as the message originator. This is set only once during message creation. This number enables receiving vehicles to know their neighborhood. The MAC address of an OBU can be set as a vehicle ID.

- **Message Identifier (M_{id}):** Message ID is a unique sequence number given to every message by the source vehicle. Message ID, in conjunction with Vehicle ID, allows receivers to distinguish between different messages.

- **Forwarder Identifier (F_{id}):** Forwarder ID is the identification number of the vehicle that forwarded the message.This parameter is modified each time a message is forwarded. Similarly to the source ID, the Forwarder ID can consist of the MAC address of the forwarding vehicle.

- **Source Coordinates(P_s):** which indicate the source vehicle's geographic coordinates. This field is not modified by vehicles that are forwarding the message. This field enables the receiver to calculate the distance between the receiver and the source.

- **Forwarder Coordinates(P_f):** It includes the geographic coordinates of forwarding vehicles. It is updated at every relay vehicle. It will help to determine the distance between the receiver and the sender. Based on this distance information, the delay time is calculated.

- **Transmission Range (MR):** It is the perceived range of communication evaluated at every node and shared in beacon and alert messages for further processing.

- **Hop-count (H):** The hop count is used to identify the total number of hops before the message reaches its destination; it is initially set to zero at the source vehicle and incremented at each forwarding vehicle.

- **Timestamp (t):** a timestamp, which is inserted in message at it's source vehicles to identify message lifetime and delay in dissemination of the message.

Inside vehicular networks, vehicles exchange periodic beacon messages with all their one-hop neighbors to share crucial parameters. Whenever a safety concern arises, it triggers the alert message to be disseminated by multi-hop communication. In this way, the vehicle alerts all the surrounding vehicles about the safety concerns by broadcasting the message. The performance of the safety dissemination scheme is measured by total coverage, average delay, and total number of hops.

4.3 Assumptions

- ✓ We assume that every vehicle is equipped with On board Unit (OBU), Application Unit (AU), and user interface. We also assume that vehicles are equipped with sensors to detect emergency situations.
- ✓ Every vehicle is equipped with Global Positioning System (GPS) to furnish location information.
- ✓ Vehicles exchange beacon messages to convey vehicle ID, vehicle position, and other information to single-hop neighbors.
- ✓ The vehicular communication is in vehicle-to-vehicle (V2V) mode, without the need of any roadside infrastructure.
- ✓ IEEE 802.11p based communication technology establish links between vehicles.

4.4 Cooperative Range Detection

In most of the existing literature, a predetermined transmission range is used to calculate delay at every relay node. In this work, the actual range of communication is derived through the use of beacon exchange. Along with other important information, beacon messages also contain the perceived range. The beacon messages contain the sender's location coordinates, perceived range, and other information such as vehicle speed, direction, etc. Whenever any vehicle receives a beacon message, it extracts the sender's location and the range conveyed by the sender. The receiver then calculates its distance (d) from the sender. The maximum from distance, range, and the receiver's own stored MaxRange parameters becomes the receiver's perceived MaxRange. The algorithm 1& 2 show the process of range detection through beacon message exchange.

Algorithm 1 Beacon braodcast process

```
for My turn do
    Send time = random (Beacon interval);
    Wait for your turn;
    if channel is idle? then
        Set Source_id;
        Set range = max(MaxRange_new, MaxRange_old);
        Set position;
        Broadcast the Beacon;
    end if
end for
```

Algorithm 2 Beacon receive process

```
Require: position
while Beacon is received do
    Retrieve the range;
    Retrieve the position = P_s;
    Calculate distance d = calculate(position, m_position);
    Calculate MaxRange_new = max(range, distance, MaxRange_old);
end while
```

4.5 Adaptive Range based Broadcast(ARB)

This section presents the Adaptive Range based Broadcast (ARB) protocol for safety message dissemination in vehicular networks. ARB validates the practicality of using perceived transmission range instead of a fixed, predetermined range value. ARB is a distributed, receiver-oriented method. receiver-oriented in the sense that the sender simply broadcasts the message without needing to select the relay nodes for further dissemination. Every node that receives the message will evaluate the respective distance from the previous sender and calculate their own delay, which is inversely related to distance. The vehicle located the farthest away will have the first chance to broadcast the message because it will have the shortest delay. If, in any case, the furthest node failed to relay the message due to packet collisions or congestion, then the vehicles behind the furthest one will get the chance to broadcast. In this way, the broadcasting process is completely distributed, and all receiving vehicles are deciding whether to broadcast or not. Upon receiving the first re-broadcast from any vehicle, the rest of the other vehicles in its communication range drop their scheduled broadcasts to avoid redundant transmission.

On receiving the message at time t, the vehicle v_i will check the *message ID* to determine the novelty of the message. If v_i receives the message for the first time, then location and range parameters are retrieved from the message and an adaptive delay is calculated. The message will be rebroadcast after the delay time expires. If the message has already been received, then v_i will calculate two distance parameters. (i) its distance from the message originator (d_s); (ii) The distance between the message originator and the message forwarder (d_f). If the value of d_s is less than or equal to d_f, then it is confirmed that the message has already propagated further, so v_i will discard the message. If $d_s > d_f$, then the receiver will cancel any scheduled broadcast of the message and reschedule it with a new delay.

4.5.1 Message suppression

Upon receiving the repeated message again, there are two possibilities. (i) The message has already progressed further. (ii) A new forwarder from the front has relayed the message. For the first case, $d_s > d_f$ will be valid, and if the message is scheduled for broadcast, then re-scheduling is implemented with a new delay calculation. For second case $d_s < d_f$ will be valid and it suggest that, message

Algorithm 3 Relay Node Selection Algorithm

Require: Coordinates of the generator, forwarder, and Range

while Alert message received **do**
    if Message is Repeated **then**
        Calculate d_s and d_f;
        if $d_s > d_f$ **then**
            if Message is scheduled for broadcast **then**
                Re-schedule with new delay;
            else
                calculate delay and schedule for broadcast;
            end if
        else
            Discard the message;
        end if
    else
        Get $MaxRange$, Calculate d_i
        Calculate Ns, my_slot, and $delay$
        Schedule forwarding
    end if
end while

is progressed further in direction of broadcast and this is it's acknolegement. So message suppression will be executed, and messages will be discarded.

4.5.2 Message broadcast

If a vehicle receives the message for the first time, then it will calculate the total number of slots (N_s) and determine its time slots (my_slot) based on Maximum range ($MaxRange$) and distance from the forwarding node (d_i). Waiting delay is calculated from the assigned slot and message is scheduled for broadcast after delay time. All the vehicles located near the boundaries of Transmission range are assigned with shortest delay and hence favoured as relay nodes. All other vehicles will implement the message suppression process when they listen to the same message backward from farthest vehicles. Figure 4.2 shows the overall process flow of messege forwarding.

Every node calculates the total number of slots for broadcast scheduling using Equation 4.1.

$$N_s = \alpha \left[\frac{MaxRange}{k} \right] \tag{4.1}$$

Here, $MaxRange$ is the maximum transmission range of the node, and k is the vehicle length plus the minimum distance between two vehicles. The multiplying factor α is added to accommodate node density-based adaptation in contention-window size. Adaptive variation in N_s based on transmission range provides less delay as compare to fixed range method. Once the maximum size of the N_s is found, vehicles based on their respective positions calculate their slot as shown in equation 4.2

$$S_i = \left(1 - \frac{d_i}{MaxRange}\right) \times N_s \tag{4.2}$$

The time slot assigned to every vehicle will be based on its location and transmission range. This time slot is converted into a delay that all vehicles must wait for before broadcasting the received message. slot is converted into delay as per equation 4.3. In this case, w denotes the waiting time and δ is the minimum delay for one-hop transmission.

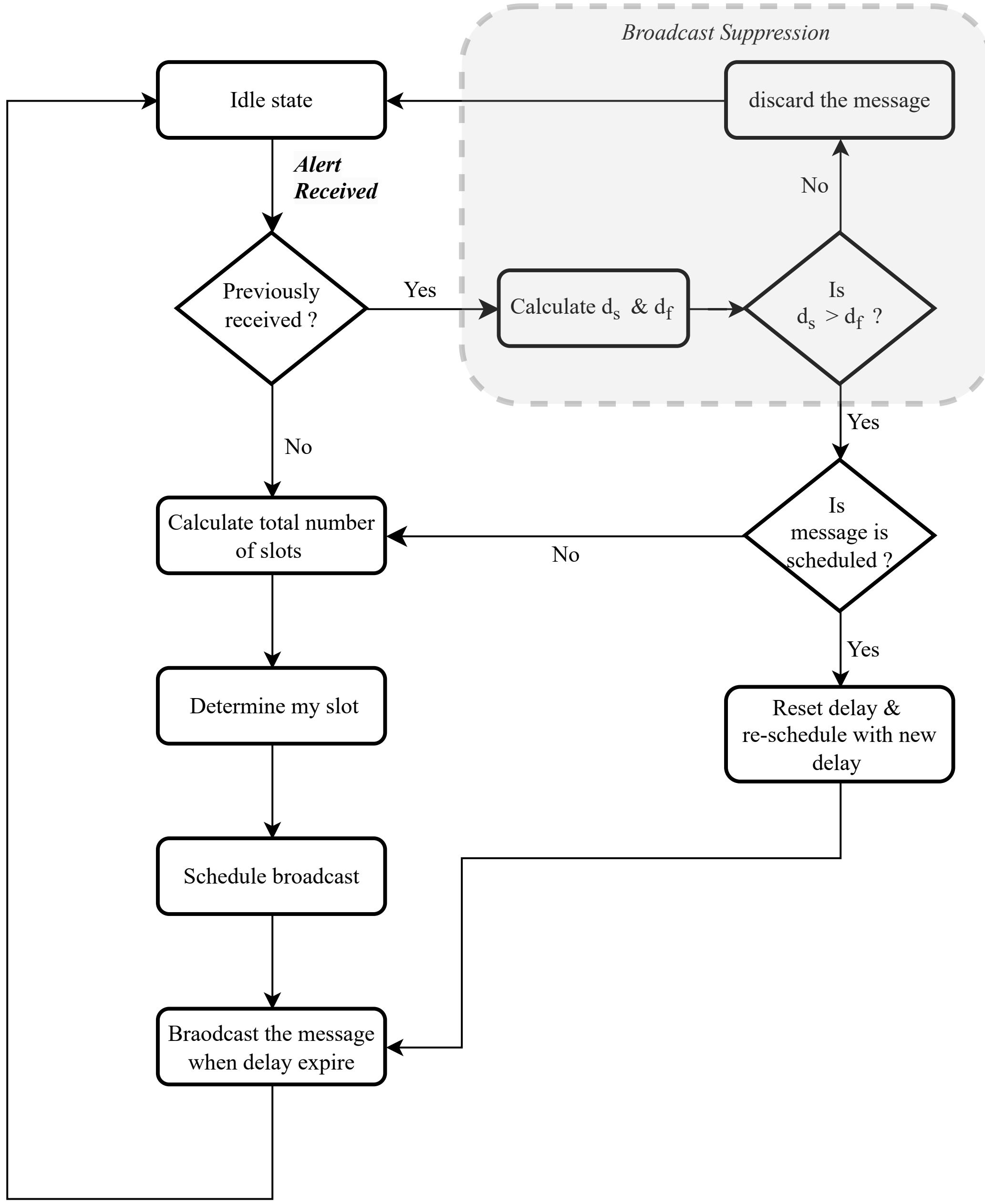

Figure 4.2: Broadcast suppression and forwarding in ARB

$$w = random(s) \times \delta \tag{4.3}$$

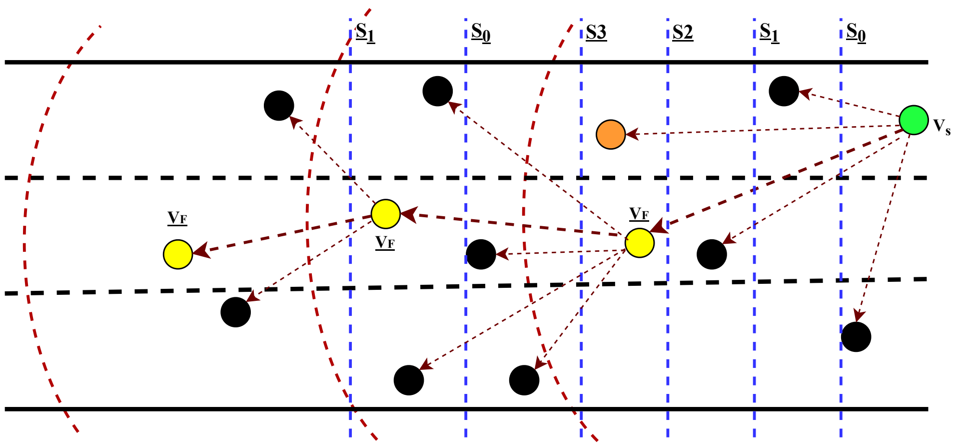

Figure 4.3: Multi-hop data dissemination in ARB

Figure 4.3 describe the process of data dissemination in ARB. The source vehicle (V_s) initiates the broadcast message. All the one-hop members of V_s receive the alert broadcast messages. For illustration purposes, the transmission range of V_s is divided into four slots (S_0 to S_3). Each vehicle determines its delay value based on its location. The vehicle that re-broadcasts the message will also append its $MaxRange$ value to the alert message so that next-hop vehicles can adapt their slots accordingly. The farthest vehicle will most likely elect the lower delay and receive priority over vehicles located closer to the sender. This mechanism allows longer distance at every hop with the lowest possible delay, and redundant broadcasts are suppressed efficiently. The randomness introduced in selecting the waiting time will reduce concurrent transmissions from vehicles located within the same time slots.

4.6 Efficient and Reliable Data Broadcast (ERDB)

As presented in Section 2.2, a lot of work has employed the distance-based forwarding node methods. In a limited test environment with moderate vehicle density, it provides acceptable performance with less delay and lower computational requirements. But when extreme network conditions exist, such as high-speed variations, poor channel conditions, and high vehicle density, failure and delay increase excessively [33], [40].

We observe that a lot of work employs greedy forwarding by electing the farthest node as the next forwarder. All the nodes located at the boundary of the communication range will have a lower signal-to-noise ratio (SNR) [50]. For links with low SNR, multipath fading and the shadow effect make connectivity unstable. Greedy forwarding-based protocols have acceptable performance in limited traffic conditions and communication scenarios. Such a protocol does not scale well for realistic traffic conditions with varying node densities. As discussed earlier, the

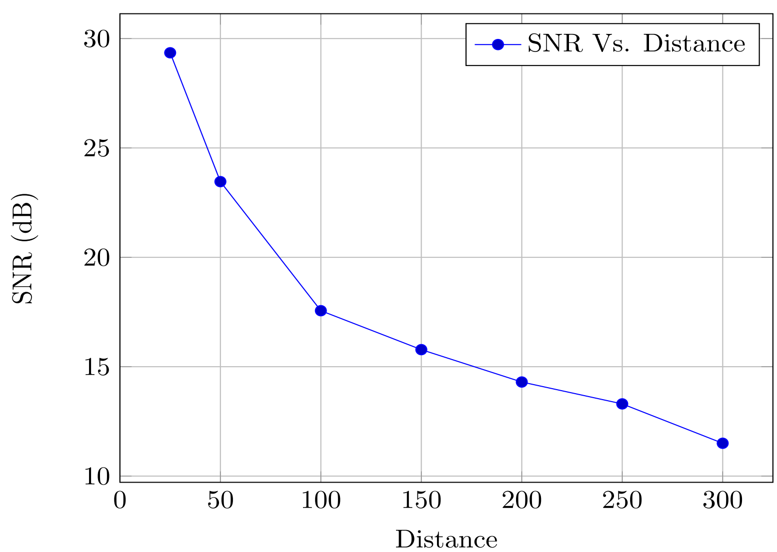

Figure 4.4: SNR(dB) Vs Distance

effective range of vehicular communication is around 300 m. Simulation-based findings suggest the SNR degrades as inter-vehicle separation increases, as shown in Figure 4.4. The packet delivery ratio (PDR) in a vehicular network will depend on the minimum received power (Pr), background noise, and efficient broadcast scheduling that reduces concurrent packet transmission [41]. Figure 4.5 shows PDR vs. inter-vehicle distance statistics for a communication range of 300 m, a data rate of 6 Mbps, and a packet size of 200 bytes.

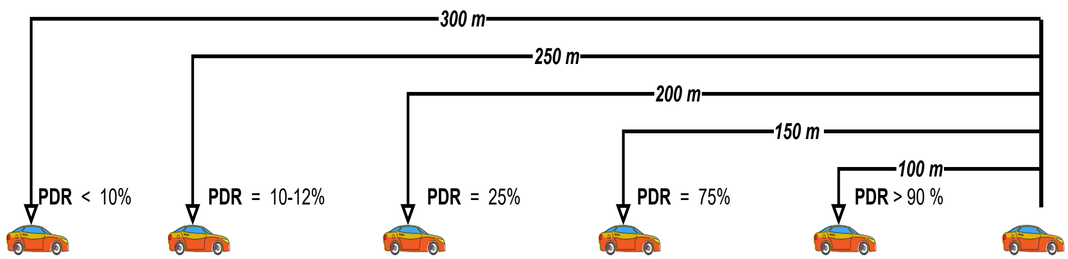

Figure 4.5: PDR Vs distance

The proposed work overcomes a few limitations examined in the reviewed work. It primarily focuses on reducing message dissemination failures and improving delay performance through the adaptive selection of next forwarding nodes. The adaptive relay node selection process prioritizes reliable relay nodes against the farthest-distance nodes to increase reliability. The next section describes the proposed modifications that exhibit good performance under lossy wireless communication.

This section presents a scalable and robust multi-hop dissemination protocol called ERDB an efficient and reliable adaptive dissemination protocol. ERDB is designed by keeping in mind the high mobility of vehicles, the large variation in vehicle density, and the unreliable channel characteristics present in vehicular communication. The protocol is used to disseminate the alert message over longer distances during emergencies. Delay performance and coverage of any multi-hop dissemination protocol are governed by the rate of failure of relaying, channel availability, and rate of redundancy in the network. ERDB uses instantaneous SNR and inter-vehicle separation to select the next forwarding node for the alert dissemination process.

4.6.1 Message dissemination process

ERDB is a multi-hop message dissemination protocol that provides fast and reliable alert message dissemination. ERDB employs an adaptive relay node selection scheme based on SNR and distance to implement efficient redundancy suppression and reliable alert dissemination. Instantaneous SNR values at every receiving vehicle represent current channel conditions and the surrounding environment. Using the SNR value in the determination of delay time along with distance slightly reduces the one hop distance but increases reliability by reducing failures in communication because of bad channel conditions. The delay time is the amount of time that each forwarder will wait before forwarding the alert. Efficient selection of delay time reduces overall message propagation delay, and SNR-based selection criteria reduce failure in packet reception because of poor SINR, propagation conditions, and random shadow and fading effects. The protocol uses the slotted contention window-based relay section method.

The total number of slots is computed by using the maximum transmission range and the minimum vehicle separation. Algorithm 1 describes the mechanism of alert message broadcast and redundancy suppression.

Figure 5 illustrates the steps involved in the functioning of the protocol. The receiving node implements SNR-based quality checking and contends for broadcast candidates depending on its position. The message-id is then used to determine whether or not the message is new. For every new message, the receiving node contends for broadcast candidates depending on its position. If the received message is repeated, the receiver will first identify its own position in the broadcast area. It calculates the forwarder's distance from the originator (d_f) and its own distance from the originator (d_s). If d_s is greater than d_f, it will participate in broadcast activity; otherwise, it will not. To broadcast the message, every node calculates the total number of slots (N_ss) for broadcast scheduling using equation 4.4

$$N_s = \alpha \left[\frac{MaxRange}{k} \right] \tag{4.4}$$

Here, $MaxRange$ is the perceived transmission range of the node, and k is the

Algorithm 4 Alert message broadcast Algorithm

Require: Coordinates of the generator, forwarder, and Range

```
while Alert message received do
    Calculate SNR_i
    if SNR_i >= SNR_th then
        if Message is new then
            Calculate d_i and N_s
            Calculate Delay and Initiallize Timer;
            Broadcast the alert, when timer expires;
        elseMessage is received again
            Calculate d_s and d_f;
            if d_s > d_f then
                if Message is scheduled for broadcast then
                    Re-schedule with new delay;
                else
                    calculate delay and schedule for broadcast;
                end if
            else
                Discard the message;
            end if
        end if
    else
        Discard the message;
    end if
end while
```

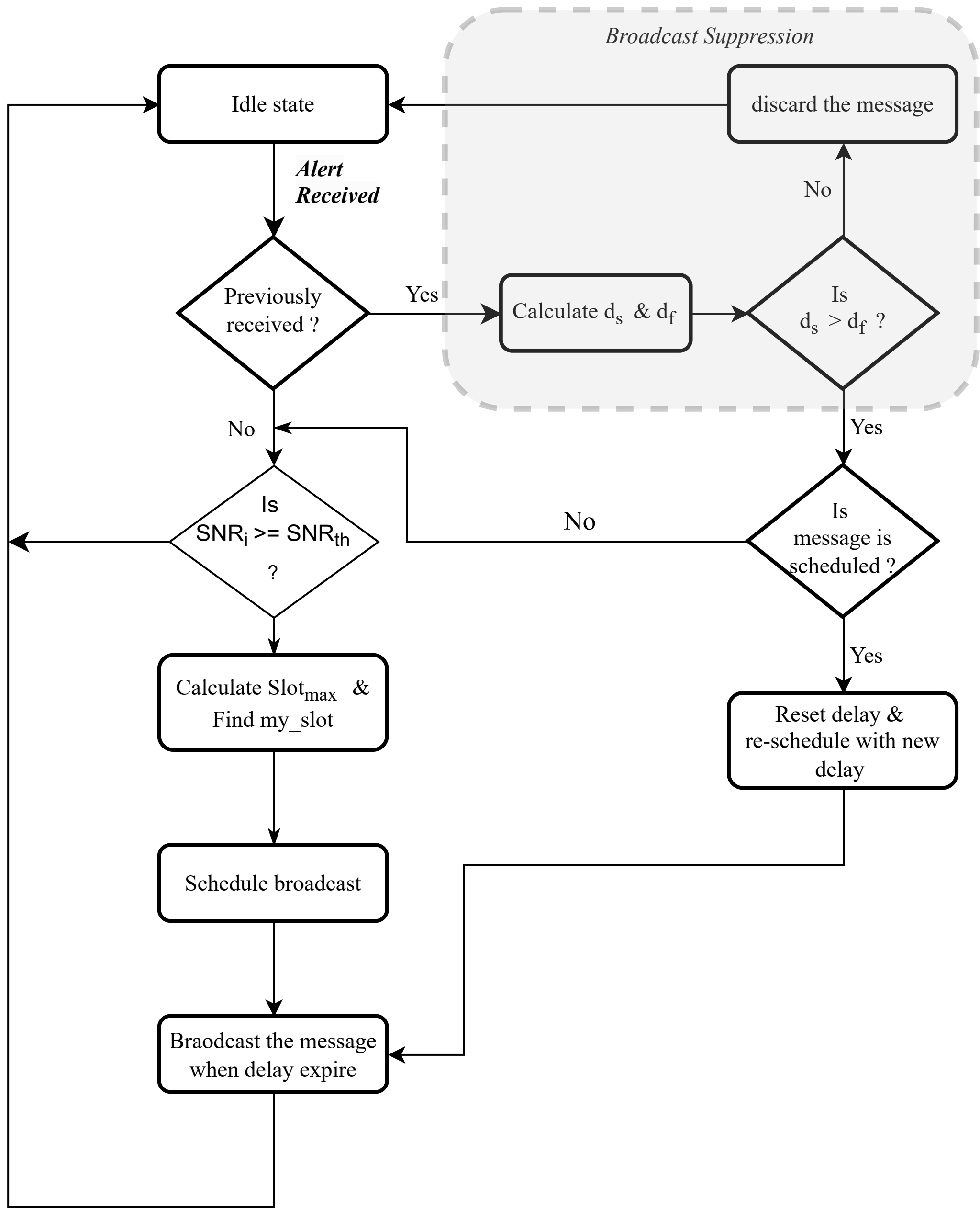

Figure 4.6: Broadcast suppression and forwarding in ERDB

vehicle length plus the minimum distance between two vehicles. The multiplying factor α is added to accommodate node density-based adaptation in contention-window size. Adaptive variation in N_s provides less delay at moderate vehicle densities and reduces the probability of concurrent transmission by employing a larger N_s at high vehicle densities. Signal-to-noise (SNR)-based screening and maximum N_s are calculated as per equation 4.5.

$$N_s(adaptive) = N_s \times \beta^{\left(\frac{SNR_i - SNR_{th}}{w}\right)} \tag{4.5}$$

Once the maximum size of the total number of slots N_s is found, vehicles based on their respective positions calculate their slot as shown in equation 4.6. Subsequently, the slot is converted into a delay as per equation 4.7.

$$S_i = \left(1 - \frac{d_i}{MaxRange}\right) \times N_s(adaptive) \tag{4.6}$$

$$w = random(s) \times \delta \tag{4.7}$$