Wiley
Security and Communication Networks
Volume 2025, Article ID 8882649, 21 pages
https://doi.org/10.1155/sec/8882649

WILEY

Research Article

Disseminating a Fair Emergency Message With V2V Communication Technology in VANET

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Received 10 December 2022; Revised 2 September 2024; Accepted 21 September 2024

Academic Editor: Vincent O. Nyangaresi

Vehicular ad hoc networks (VANETs) are nodes moving at a high speed compared to mobile ad hoc networks (MANETs). Network-connected nodes can exchange safety or nonsafety messages within themselves or other infrastructures, such as vehicle-to-vehicle (V2V) or vehicle-to-everything (V2X). In vehicular communication, emergency messages are crucial for safety and must be distributed to all nodes to alert them of potential issues. Different broadcasting methods, such as single-hop, multihop, and flooding, have disseminated these messages as part of the broadcast storm mitigation strategy (BSMs). Disseminating safety messages in an urban scenario is challenging due to crowded nodes participating in the communication. The main issues are packet broadcast storms, packet collision, and end-to-end delays (E2EDs). When multiple nodes rebroadcast the same message, packet redundancies occur, which can impact the performance and stability of the network, especially in urban areas. This study proposes a safety message dissemination (SMD) approach to address these broadcast storms. This approach can select a single relay node within a single transmission range. The node with the longest time to leave, high density, and appropriate signal strength was chosen as the relay node. This approach ensured that a fair safety message was disseminated to all nodes. The real-world scenario was also generated using the simulation of urban mobility (SUMO) traffic generator. The performance of the proposed approach was also analyzed and compared with existing standard algorithms, such as fast broadcasting and the effective emergency message dissemination schemes (EEMDS) approach. The results showed that the SMD outperformed all of them in terms of E2ED, packet loss ratio (PLR), and packet delivery ratio (PDR). It has enhanced EED by 0.54% for 20 and 60 nodes at different simulation times, PLR by 4%, and PDR by 17.5%. As the number of nodes and simulation times increased, E2ED and PLR increased proportionally, while PDR decreased.

Keywords: basic safety message; communication range; rebroadcast; relay node; SMD; VANET

1. Introduction

A vehicular ad hoc network (VANET) is an ad hoc network that is not controlled by a central controller or base station [1–3]. It takes vehicles and communication infrastructures as nodes to realize vehicle-to-vehicle (V2V) and vehicle-to-everything (V2X) communication. It is also a wireless mobile network with a new feature characterized by a list of moving nodes with high speed, specific directions, frequent link disconnection, and network link unreliable due to an intermittent network connection, complex communication scenarios, and rich external equipment. The intelligent transport system (ITS) has become the dominant technology in vehicular network communication [1] that controls VANET information exchange. In the current era, modern vehicles are manufactured with embedded equipment, which allows them to connect to the Internet and exchange messages within themselves or the environment. These modern vehicles, those able to share information, are designed to improve the transportation system. Even smart vehicles are becoming as automated as those that can be derived without human intervention in case, they can improve human error and labor. They can also facilitate any requirements by exchanging information with everything. The rapid development of smart vehicles in vehicular communication technology is driven by the need to avoid road hazards, thereby saving lives and protecting infrastructure from damage. Additionally, it aims to enhance the sharing of infotainment.

This attractive technology in vehicular communication was achieved by vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-network (V2N), vehicle-to-pedestal (V2P), vehicle-to-everything (V2X), and cellular vehicle-to-everything (C-V2X). V2V technology is the current communication technology that allows message dissemination among vehicles to inform what is exactly found around the road. It allows vehicles to send and receive data among themselves. To establish a connection among nodes, either dedicated short-range communication (DSRC) for V2V or C-V2X for V2X communication technologies has been used. These technologies are specifically used at the physical and MAC layer of VANET protocols. DSRC technology was embedded in the onboard unit (OBU) and roadside unit (RSU) to provide complete functionality in vehicular communication. It allows V2V communication through the PC5 interface. The PC5 interface is divided into the physical side link share channel (PSSC) and the physical side link control channel (PSCC). This single channel was logically classified into two subchannels for sharing and controlling shared information. DSRC is more secure and reliable but has less coverage area when compared with C-V2X communication. It provides services such as accident warning, lane change warning, crossroad warning, traffic management, and infotainment dissemination among vehicles. However, it is affected by non-line-of-sight (NLOS) infrastructures and hidden nodes. The second technology is C-V2X communication, which uses the cellular network to connect and exchange information among vehicles such as V2V or V2X [2]. This technology was proposed by the third generation partnership project (3GPP), which releases 14 and 15 to meet the criteria of 5G technology. C-V2X communication technology has two modes: mode3, which allows communication between vehicles and base stations through the UU interface, and mode4, which allows communication among vehicles directly through the PC5 interface. To satisfy those issues, 5G-NR technology was proposed, which is compatible with C-V2X communication technology [3].

Disseminating fair messages among nodes is challenging due to the motion of vehicles. They change their topology within microseconds, making it difficult to manage connected properties in the network area. Topological connection and disconnection of VANET are the main challenges in vehicular communication, causing instability of the network and frequent link failure. Since nodes move at high speed, they enter and exit the connectivity in milliseconds rather than seconds. A little delay is dangerous because time is a critical attribute in VANET, especially for safety message dissemination (SMD). To share information wisely in VANET requires an approach that disseminates data without delay. Due to this, the best-fit approach and recommended method in the existing literature is the broadcasting approach rather than unicast, anycast, or multicast. So, in vehicular communication, the broadcasting approach is the best technique for sharing information fairly and in a timely manner, especially since it is recommended for SMD [4, 5]. In this regard, when many nodes are rebroadcasting information to each other, it can bring high traffic congestion, channel load, broadcast storm, collision, and high computational tax on nodes.

These can overwhelm the communication channels as every node struggles to keep up with processing the flood of messages. When this happens, network performance highly degrades. Thus, without missing the recommended approach to overcome such impacts of broadcasting problems, minimizing the number of rebroadcasting is an exciting research challenge to select the best performance forwarder from the list of neighbors. Accordingly, different authors have adopted various approaches to solve SMD on the road, caused by many rebroadcasts. The authors in [4] proposed an approach that minimized packet broadcast storms and overhead on the road by selecting forwarder nodes that would reduce the number of rebroadcast nodes. Many other authors [5–13] have proposed an algorithm to disseminate safety messages to all nodes that will minimize collision, broadcast storm, and latency by selecting forwarder nodes that can reduce the amount of rebroadcasting, which is an input for the problem mentioned. As the number of populations and vehicles increases proportionally, traffic control systems, data dissemination, and accident control become more challenging. When many nodes rebroadcast the same information within the same transmission range, broadcast storms and packet collisions obviously happen. The main thing is disseminating fair messages between nodes with no or less packet collision. Even though various researchers have considered such a problem, it is still necessary to deal with selecting vital nodes within the same transmission range that prevents broadcast storms. Many of them try to solve a highway scenario while, in our case, urban scenarios have been considered. Thus, the proposed solution focused on preventing broadcast storms in urban scenarios, specifically on the cross-sectional road, due to many nodes rebroadcasting the message.

The proposed SMD algorithm addresses packet collision and broadcast storm issues in urban VANETs by combining priority-based message forwarding and adaptive broadcasting techniques. The SMD algorithm effectively reduces redundant transmissions by assigning higher priority to safety-critical messages and employing a dynamic broadcast suppression mechanism. It controls the timing of broadcasts based on current network conditions. This prioritization ensures that vital safety messages are disseminated promptly. At the same time, the adaptive approach mitigates the risk of packet collisions. It minimizes the likelihood of a broadcast storm, thereby enhancing the overall reliability and efficiency of communication in VANETs. SUMO traffic generator and NS2 network simulation to minimize the number of broadcast storms have been employed to realize the proposed approach.

The novel contribution of this paper is disseminating a fair emergency message in vehicular communication by minimizing the number of rebroadcasting nodes at a cross-sectional road. As flooding approaches, packet broadcast storms occur, leading to high congestion problems, especially in dense areas, and a high probability of packet collisions during message dissemination. Additionally, increasing the computational task to each node consumes time and fails under latency. To overcome those challenges, various authors deal with different techniques, but our main contributions are stated as follows:

- Fair Emergency Message Dissemination in Vehicular Communication:

  The proposed SMD algorithm ensures the fair dissemination of emergency messages in vehicular communication using the V2V technique. The method focused on delivering timely and accurate information to all nodes, thereby enhancing road safety and network reliability.

- Selection of a Single Relay Node:

  The proposed SMD involves selecting a single relay node based on node density, average received signal strength (avr_rss), and node time-to-live (nodes_ttl) in urban scenarios. These selection criteria help maintain efficient communication and minimize redundancy.

- Handling Packet Collision and Broadcast Storms:

  The proposed SMD addresses the issues of packet collision and broadcast storms for fair message dissemination. This method ensures that emergency messages are effectively distributed without overwhelming the network, enhancing performance and stability.

- Performance Evaluation:

  The performance of the proposed SMD is assessed through metrics like end-to-end delay (E2ED), packet delivery ratio (PDR), and packet loss ratio (PLR). The findings demonstrated that the proposed algorithm effectively addressed timeliness, reliability, and robustness, all of which are essential for successful emergency message dissemination in vehicular networks.

2. Related Work

Vehicular connectivity is enabled by either DSRC or C-V2X communication technologies. DSRC facilitates direct V2V communication using the PC5 interface, while C-V2X supports data exchange between vehicles and cellular networks through the air interface [11]. Both communication methods support V2X technology, with DSRC utilizing the IEEE 802.11p standard for the physical and MAC layers, and C-V2X relying on long-term evolution (LTE) technology as proposed by 3GPP [12]. V2X communication enables the exchange of data between vehicles, infrastructure, and other roadside elements, enhancing overall accessibility and connectivity in vehicular networks [4, 13].

Authors in [4] proposed an algorithm to disseminate emergency messages by selecting the forwarder node. They used lane ID, distance, and direction of nodes to select the node as a forwarder. It is suitable for single-hop data dissemination and if an emergency happens exactly in the specified lane. The forwarder node was selected when the node's lane ID and the sender's lane ID are the same. Indirectly, as the number of lane IDs increased, the number of forwarder nodes also increased in proportionality. When the number of forwarder nodes is increased, they have the same opportunity for message rebroadcast, which will increase packet collision and broadcast storm.

The author in [5] proposed trajectory dissemination (TBD), which transforms data over the network based on the density of the vehicles from the source to the region of interest (ROI). This approach uses cellular to disseminate data to the ROI. TBD disseminates the message based on the relay to reach the destination. It calculates the time and length between the relay nodes to transmit the message. The time expired will be checked based on the schedule and canceled.

Additionally, the ROI should be identified before the communication starts, and a scarcity of messages will happen for those out of the region. The nodes that are specified for forwarding the message were selected by calculating the shortest path using the Dijkstra algorithm. They have used oriented transmission methods to avoid collision and unnecessary transmission, as indicated in the following figure. However, it allows nodes within the conic shape to be selected as relay nodes. Many nodes are selected as a relay, and since they are going to retransmit the message, there is the chance for packet collision and broadcast storm.

In [6], forwarder-based data dissemination was proposed to select the forwarder with parameters such as distance, density, and time to leave the transmission range. They have taken a far distance from the source node, which is good for coverage, high dense node to broadcast for all other nodes easily, and the node that leaves the communication range before others to reach the emergency message to the following communication range, respectively. In the proposed system, a single hop collects the information of neighbor nodes and assigns the best forwarder based on the specified parameters. The selected forwarder rebroadcasts the message until all the areas of interest receive the message. It is a sender-based multihop dissemination approach. This causes the source node to fail under high complexity since it calculates and selects the forwarder node. It also allows for nodes that fulfill both criteria with long-distance and high node density. At this time, more than one node will be selected as a relay node that will rebroadcast the messages later.

The authors in [7] proposed signal-to-noise ratio (SNR)–based rebroadcasting to minimize collision and broadcast storms during early warning message dissemination. That has focused on the distance of the receiver node and sees the SNR assign the node to rebroadcast the message. The node will rebroadcast if it is located outside of the ring. The proposed study is independent of neighbor information that did not require beacon exchange and a central or base station or RSU. It simply identifies the next hop from SNR. The probability for rebroadcast is critically focused on the distance between the source and forwarder node, for which priority is given to the farther distance. They have also considered a large suppression range when choosing the forwarder node.

In [8], the author proposed an effective emergency message dissemination scheme (EEMDS) in an urban scenario to minimize broadcast storms, collisions, and overhead. They have considered link stability to select relay nodes that will rebroadcast the emergency message in addition to the cluster head. They have a select cluster head to control cluster members and manage emergency dissemination. The source node will broadcast to the cluster head, and it will select a forwarder based on link quality for further coverage. The approach is good in case of infotainment dissemination rather than for emergencies since it fails under delay. The cluster head also falls under many tasks, such as managing cluster members, selecting relay nodes, and broadcasting messages received from the source node to the selected forwarder. Within the same communication range, at least two nodes (cluster head and gateway) will rebroadcast the message, increasing packet collision, broadcast storm, and packet overhead.

The authors in [9] proposed an algorithm to reduce the number of broadcast storms in the vehicular network for message dissemination with selective, reliable communication to the zone of interest. The proposed algorithm classifies the vehicles as a connected set of vehicles (CSV) that will disseminate messages based on the threshold value and timestamp and eliminate a set of vehicles (ESV) that will stop message dissemination based on their distance and threshold values, respectively. But both of their reliability are considered to be classified as CSV or ESV. Additionally, based on threshold and time stamp values, they have clustered the vehicles as cluster heads and cluster members that will distribute the message to the interested zone. VANETs are ad hoc networks that change their topological connectivity frequently [10]. So, various authors proposed many techniques to disseminate any message fairly within a specified time and to all nodes. The main things are disseminating fair messages between nodes with no or less packet collision, broadcast storm, overhead, and redundancy. Basically, to disseminate a fair safety message among vehicle authors' beliefs, minimize the number of nodes that will rebroadcast later [12, 13]. To do this, some select cluster heads, forwarder nodes, or gateway nodes among all vehicles are based on different parameters. Even though various authors have applied their best, it is still necessary to deal with it.

The authors in [14] proposed emergency message dissemination with a dynamic cluster head selection approach. The authors aim to select the best forwarder based on the optimal path to reach the destination without delay. They have also used a hybrid approach that combines vehicular communication with vehicles and infrastructures. The vehicles are selected as leader cluster head, ordinary cluster head, multipoint relay, and cluster members based on the location, direction, and speed of the vehicles. Each vehicle communicates with eNodeB based on its communication range. But the clustering approach that disseminates safety messages from source to destination consumes time since the message was transmitted from members to the cluster head and then RSU. Each vehicle is classified under clusters. When they broadcast the message, there is a high probability of packet collision, broadcast storm, and overhead.

The author in [15] proposed effective broadcasting message dissemination to overcome the challenges raised due to flooding with algorithm source Lateral Crossing Line (LCL) that selects relay nodes based on the vehicle's location. Those authors describe the data dissemination techniques as probabilistic or opportunistic-based, timer/delay-based, cross-layer-based, digital map-based, and network topology–based [16]. The vehicles set rebroadcasting schedules, and if the duplicate message was there, they would dismiss their rebroadcasting. It also selects the relay nodes based on the direction from the north, west, east, and south relays that were selected based on the location of the emergency. The nodes will assign themselves based on back-off timers. Here, there is the probability that a single node will receive the message from two different relay nodes. So, it increases the packet collision and broadcast storm [15].

In [17], to disseminate an efficient message in vehicular communication, they proposed fuzzy logic-based and nonfuzzy logic that select forwarders based on the long distance, maximum speed, low density, and source node selects the next forwarder, respectively. Since simple broadcasting is inefficient, an efficient forwarder should be selected to reach the destination. Fuzzy logic often combines numeric and linguistics, which makes it more important than the other [18]. It is a good algorithm that will work with different conditions without complexity and with high performance. The proposed algorithms are good when several nodes are scarce and have a single-hop broadcasting approach. However, it can be failed when the number of nodes is dense and closest to the source node.

Further, in [19], delay-sensitive broadcast challenges were addressed by considering edge-based forwarder nodes. A federated learning client that can forward the message by conducting a local training model was selected based on vehicle velocity, distribution, and wireless link connectivity to disseminate the messages among vehicles [20] fairly. Furthermore, communication resource management was considered among the vehicles in [21] using spectrum sensing scheduling (SSS). In short, the research works conducted so far need to be improved in mitigating the broadcast storm problem to disseminate emergency messages in vehicular communication [22, 28]. Therefore, fairly disseminating emergency messages requires an urgent demand in order to overcome challenges raised in vehicular communication, such as high packet collision, traffic message congestion, broadcast storms, and channel loss. The study selects a qualified node from the list of receivers within the same communication range for rebroadcasting the given messages in vehicular communication. A summary of the literature review is listed in Table 1.

3. Materials and Methods

This "Materials and Methods" section comprehensively overviews the simulation setup, configurations, and methodologies used to evaluate the proposed algorithm.

3.1. Proposed Architecture. This study proposed SMD, a solution that overcomes the number of broadcast storms in VANET in urban scenarios at cross-sectional roads. We have adapted IEEE 802.11p/WAVE standards of vehicular communication architecture to facilitate communication among nodes. These technologies allow any type of communication, whether V2V, V2I, or V2X. So, by adopting these technologies, we have added the following proposed solution, as indicated in Figure 1.

To minimize the issues of emergency message dissemination in vehicular communication, such as broadcast storms, we have proposed a new approach based on the relay node selection method. In multihop communication, we have selected the relay node that has reduced the number of flooding messages; in case, it overcomes collision and broadcast storm in vehicular communication. To achieve this goal, we have selected the parameters that are used to identify the node from others to make it selective. The challenge is to pick a single node that would be rebroadcast among all receivers. The study considered node parameters such as node density, medium received signal strength, and node time to leave the communication range. The node that fulfills these parameters was selected as a relay node to rebroadcast the emergency message.

Density means the number of nodes found in a specific area. It is based on the number of vehicles. Using this parameter, we have used node density to select a single node from dense nodes. We have used beacon messages to calculate the density of nodes. This beacon message is used to identify active nodes and node lists. So, from these node lists, the node that has received many beacon messages compared with others was taken as a dense node.

```
void.
BroadcastbaseApp:
process_data_BroadcastSMD () method. The sample is.
If (rcv_pkt. find (data- > g_id ()) ≥ rcv_pkt. find (data- > g_nhop ()))
{
  ……………
    }
```

Nodes' Time to Live (nodes_ttl): This is taken to determine the duration of the node that it will stay in a specified communication range. If the node has a minimum time to stay in the communication range, it was selected as a relay node based on this parameter. The node has estimated its time to stay in the communication range from the waiting time between the source and destination nodes. The nodes_ttl can be determined from the time waiting to choose the receiver by the source node and the receiver's waiting time to receive the message from the source. Here, both sender and receiver nodes are waiting for each other. If the sender node waits a long time, it can be estimated that the receiver node is far from it and is going to leave the transmission range.

Average Received Signal Strength (avr_rss): It is used to check the data's perfectness and determine the delivered packet quality. The receiver receives high-quality data if the signal strength between the source and destination node is high. It can be high, medium, and low as the distance between the source and destination node increases. The node which received medium signal strength was selected as a relay node compared with the others.

In the proposed solution, we have put the code of nodes_ttl as the following lines:

```
t_- > rcv_pkt[p_].slot_choosen = slot_choosen;    //declaring source node's waiting time
t_- > rcv_pkt[p_].slot_waiten = slot_waiten; //declaring receiver node's waiting time.
```

If the difference between the source's and receiver's waiting time is less than slot_choosen or slot_waiten_ time, the nodes_ttl is short. So, this node is selected as a candidate for the relay node in case of nodes_ttl parameter.

slot_choosen—slot_waiten.

Simply it was added in this below method.

```
Void MyBCastCWTimerexpire (Event∗ e)
{
    t_- > rcv_pkt [p_].nhop = hops_+1;
    t_- > rcv_pkt [p_].slot_waiten = slot_waiten_;
    //added code to estimate nodes_ttl
  t_- > rcv_pkt [p_].slot_choosen = slot_choosen_;
  If (slot_choosen_ ||slot_waiten_ > (slot_choosen—slot_waiten))
{
  t_- > rcv_pkt [p_].value = true;//able to forward data.
    }
  If (! (t_- > rcv_pkt [p_].value)) {/∗ I haven't still received pkt from opposite direction… ∗/
    //print: forward time src_addr pkt_id = flow_id
    fprintf (traceFile, "f %.9f %d % d\n",Schedulerinstance().clock(),nodeid,p_);
    fflush (traceFile);
    fflush (stdout);
    t_- > rcv_pkt [p_].value = true;/∗ I'm sending p_, so I won't send it again!! ∗/
    t_- > send_broadcast (p_);
    free (t_- > rcv_pkt[p_].cwt);/∗ I don't need this timer any more time ∗/
  }
}
```

Table 1: Summary of the literature review.

References	Scheme	Pros	Cons
[2]	An aggregator-specific V2V algorithm for unidirectional regulation was developed based on PC5 method.	The average level of power draw for electrical vehicle charging influences the aggregator's profit.	An ad hoc network that is not controlled by a central controller or base station
[4, 5]	A novel current-sourced bidirectional inductive power transfer interface and trajectory-based dissemination (TBD) for V2G was proposed.	The direction and amount of power flow, as well as the magnitude and relative phase of voltages, are key factors to consider.	Increased packet collision and broadcast storm
[6–8]	An optimal scheduling algorithm was developed for V2G energy and ancillary services.	Factors such as aggregator profit, system flexibility, peak load shaving, and customer cost are all considered.	One node has been selected as a relay node that will rebroadcast the messages later.
[12, 13]	The information spread problem was introduced within a combined V2I and V2V communication system.	System throughput and packet error ratio are crucial metrics to consider.	Not considered broadcast storm, overhead, and redundancy
[14]	Researched an image sensor-based visible light communication system for use in V2I and V2V applications and used emergency message dissemination method with a dynamic cluster head selection.	Incorporating safety applications	High probability of packet collision, broadcast storm, and overhead.
[17]	Explored an EV switched-reluctance motor drive that utilizes a battery/supercapacitor and incorporates V2G capabilities used fuzzy logic method	The system's characteristics include vehicle parameters.	It can be failed when the number of nodes is dense and closest to the source node.
[20]	Developed a modeling approach based on mixed-integer linear programming for V2G and V2H	Consider optimum power cost	Distribution of power with user and wireless link connectivity is poor.
[21]	Implemented a data dissemination system combining I2V and V2V communications using spectrum sensing scheduling.	Broadcast protocols have been considered.	Increased complexity and latency due to dynamic spectrum availability and coordination challenges.
[16, 22]	Studied a decentralized resource allocation mechanism using deep reinforcement learning for V2V and V2I communications.	Capacity, latency, PLR, and E2E	The potential for instability and suboptimal performance due to the unpredictable and dynamic nature of the vehicular environment.

Table 1: Continued.

References	Scheme	Pros	Cons
[23, 24]	Created a spectrum sharing and power allocation design tailored for V2V and V2I communications.	Critical factors such as reliability and capacity are considered.	Risk of increased interference and complexity in managing the diverse and fluctuating communication demands of vehicular networks.
[25]	Developed a two-way communication framework for V2B and V2G energy management in a smart building using integrating blockchain technology with IoT devices	Total cost considered.	Significant computational and energy overhead required for processing and maintaining the blockchain, which can strain resource-constrained IoT devices.
[26]	Put forward a distributed resource-sharing scheme using multiagent reinforcement learning method for both V2V and V2I links.	Parameters such as sum capacity and delivery rate are considered.	Slow convergence and coordination issues among agents, leading to suboptimal resource allocation in highly dynamic vehicular
[27]	Proposed queueing theory–based analytical models describing the communication performance of C-V2X or LTE-V.	Transmission power, PLR, PDR, and packet transmission frequency are considered.	Rely on simplified assumptions about traffic patterns and network conditions, which may not accurately capture the complexities and variability of real-world vehicular communication scenarios.
[16]	V2E computation offloading that prioritizes privacy preservation in both V2I and V2V scenarios.	Execution time, E2E, and energy optimization	Increased latency and reduced computational efficiency, as the added privacy mechanisms can introduce overhead and slow down the offloading process.
[18]	Proposed a secure and efficient V2G energy framework that integrates blockchain, IOT, and contract theory.	Considered efficiency of task offloading and reliability	High computational and energy costs, which could strain the limited resources of IoT devices and challenge the scalability of the system.
[28]	Suggested rationality and Q-learning techniques for V2X communication.	Considered accuracy, sensitivity, and positive predictive/correction distance	Slow convergence to optimal strategies and require extensive exploration and learning phases, which can lead to inefficient use of network resources and higher latency during the training period.

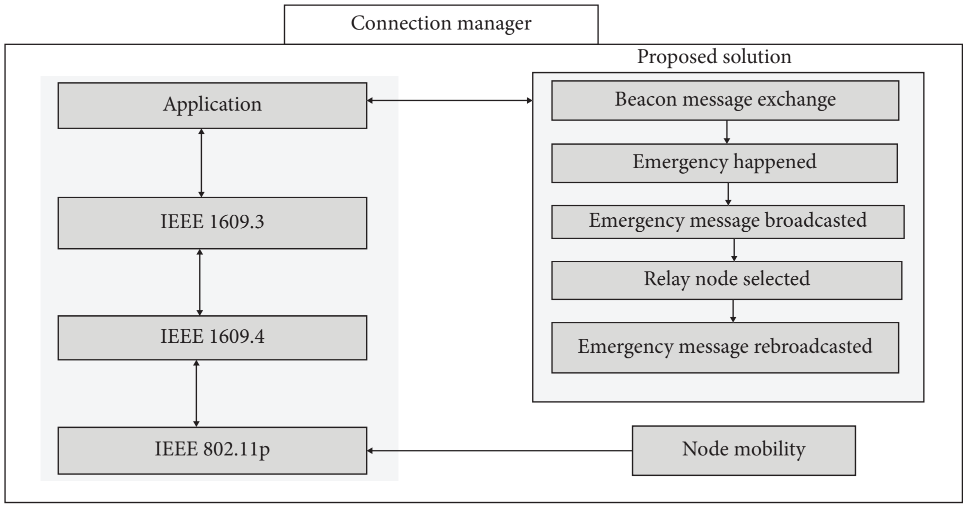

Figure 1: Proposed architecture.

3.2. Beacon Message. In the ad hoc network, nodes have freely exchanged beacon messages to establish a link among themselves. Nodes also used beacon messages to check and identify the activeness of the nodes in vehicular communication concerning their communication range. Beacon message consists of basic vehicle information such as speed, direction, and position. Additionally, the node's ID which uniquely identifies the node from the others in the entire communication can be added to beacon messages. Shortly, we have described the content of the beacon message in Table 2.

In the ad hoc network, nodes have freely exchanged beacon messages to establish a link. Nodes also used beacon messages to check and identify the activeness of the nodes in vehicular communication concerning their communication range. Beacon message consists of basic vehicle information such as speed, direction, and position. Additionally, the node's ID can be added to beacon messages, uniquely identifying the node from the others in the communication. The content of the beacon message at the receiver node is listed in Table 3.

From this table, vehicles easily predict their density and where they are found with other nodes. The flow of beacon messages in nodes communication is described in the diagram below as indicated in Figure 2.

Hereafter, nodes have registered their status using the beacon message. Information must be updated periodically as it moves from one place to another. So when it moves, the status of the node, such as position, speed, and direction, is changed periodically. In general, a beacon message is a combination of parameters: speed, position, time stamp, and direction.

3.3. Emergency Message. The original message that will be disseminated among vehicles to handle accidents on the road is an emergency message. The author in [23] described that an early warning message was disseminated among vehicles with the help of RSU. RSU will broadcast it to every node or other RSU based on the accident. The author also described that the early warning message was disseminated with and without a relay node. The relay node is used when RSU fails to reach all nodes, and the scarcity of RSU happens. This emergency message should have been disseminated fairly since it is sensitive information that impacts human life and resources. The emergency message has an identity that uniquely identifies itself from the ordinary message when the source node broadcasts it. It was disseminated with node ID, position, emergency ID, and time when it happened. From emergency messages, neighbor nodes estimate the position of the source node and prepare themselves for rebroadcasting if they fulfill the criteria from neighbor lists. Emr_time, which was sent when an emergency happened, is used to inform nodes at what time the emergency occurred. From this, nodes will receive or discard the emergency messages. The content of the emergency message is summarized in Table 4.

3.3.1. Emergency Occurrence in the Proposed Solution. An emergency can be happened on the road due to many factors. It can happen when vehicles that are crossing the road in different directions met each other. Besides this, it can happen when a single node stopped at the center of the road. As described in Figure 3, when a node was stopped at the center of the road while crossing, an emergency message can be generated. The nodes that are moving in the direction of the stopped node will receive the emergency message. So, before they fail under accident, they should have been informed about the situation. At this time, the emergency message was generated by the source node that was represented with red color in NS2. Shortly, the possibility of emergency generating was described in the flow chart in Figure 4.

An emergency can also happen when one or more vehicles stand on the road while moving. It will broadcast its position and direction to other nodes. Based on the received message, nodes will take action. In accident formation, the position of nodes plays a vital role since location is sensitive for vehicles and captured for service at any time.

Table 2: Contents of the beacon message.

Veh_id	Veh_pos	Veh_sp	Veh_dir	Timestamp

Note: Veh_id: vehicle identity, Veh_pos: vehicle position, Veh_sp: vehicle speed, and Veh_dir: vehicle direction, respectively.

Table 3: Contents of beacon message at receiver nodes.

Veh_id	**Veh_pos**	**Veh_sp**	**Veh_dir**	**Timestamp**
1- N	(xi, yj)	km/hr.	+/−(x,y)	min:ss: ms

Note: 1-N: number of vehicles, (xi, yj): position of each vehicle, +/− (x, y): the same or different direction, and min: ss: ms: minute, second, and millisecond, respectively.

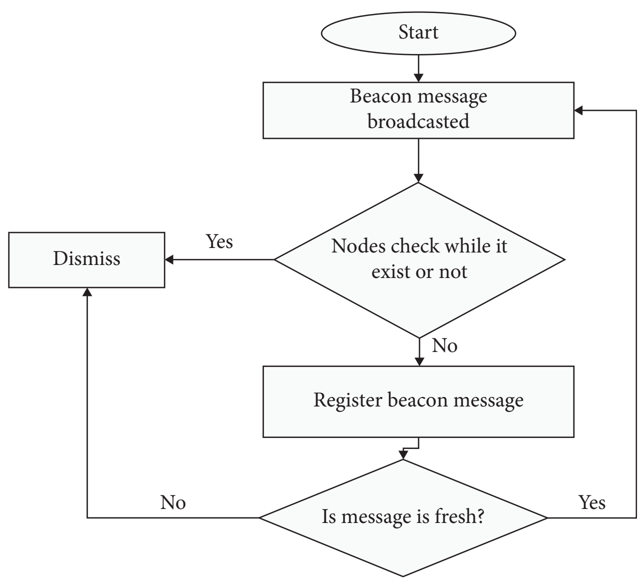

Figure 2: Beacon message dissemination.

Table 4: Contents of an emergency message.

Veh_id	Veh_pos	Emr_id	Emr_time

Note: Veh_id: vehicles source id, Veh_pos: vehicles emergency position, Emr_id: emergency identification, and Emr_time: at a time when an emergency happened.

3.4. Relay Node Selection. Emergency message dissemination is a challenging task that requires high focus to be overcome. To reduce the simple flooding communication technique that results in a high broadcasting storm and collision, a selected relay node that rebroadcasts the emergency message was selected with a proposed solution. The relay node is the node that was selected for rebroadcasting the message if it fulfills the criteria compared with other nodes. Besides this, the node that is moving to the source node or moving to the emergency place can be selected as a relay node. A vehicle with high density and medium received signal strength and stayed short in the communication range was selected as a relay node for rebroadcasting the emergency message. To select the best relay node, selecting the best parameters that meet the criteria of nodes is mandatory. Due to this fact, it still requires selecting the best relay node that critically meets the requirement of emergency message dissemination in vehicular communication for fair message dissemination.

In our study, we have selected the best relay node based on parameters such as node density, avr_rss, and nodes_ttl. The vehicle density was derived from several beacon messages that the nodes received from each other. The node that received a high number of beacon messages compared with other nodes was selected as the relay node in terms of density, while nodes_ttl was checked as it has a short period to stay in the communication range. The avr_rss is calculated from the coverage of the source signal. The node with medium avr_rss was accepted as a relay node, while very low signal strength is not enough to rebroadcast safety messages. We have assumed that each vehicle is equipped with GPS, and the source node will estimate its communication range. From the estimation, those vehicles calculate their received signal strength and put their capacity as strong, medium, or low from the format of signal strength. In the case of our study, nodes with medium received signal strength were taken as relay nodes with the combination of their density and nodes' time to leave. When nodes have the same range of received signal strength, they will be separated by their density and nodes' time to leave (nodes_ttl) from the source node. This means there is no way in which two or more nodes can fulfill these three conditions at the same time.

To calculate *avr_rss*, we have used the following equation:

$$\mathrm{avr}_{\mathrm{rss}} = \frac{(\mathrm{rssMin} + \mathrm{rssMax})}{2}, \tag{1}$$

where avr_rss represents average received signal strength, rssMin minimum received signal strength, and rssMax maximum received signal strength.

Each node calculates its own received signal strength and puts them as high, medium, and low signal strength. Some of our estimations to level the received signal strength are shown in Table 5. From this estimation, the node that has very good to good status was taken as a relay node to rebroadcast the emergency message.

The procedure to select a single node as a relay node that will rebroadcast emergency messages later is indicated in the below diagram. As described in the diagram, in the initial phase, nodes within the communication range of the source node received an emergency message. Then, nodes will check whether the broadcasted message already exists or not. If it is new, message nodes will identify whether they are moving to an emergency place. If an emergency message was enabled, relay node selection was decided, and the safety message was rebroadcast. Besides this, all receiver nodes check their density and calculate their signal strength. The nodes that satisfy these three conditions mean minimum nodes_ttl, high dense, and medium signal strength were selected as relay nodes. In general, we have included the steps, so it can be easily understood how the relay node was selected, as shown in Figure 5.

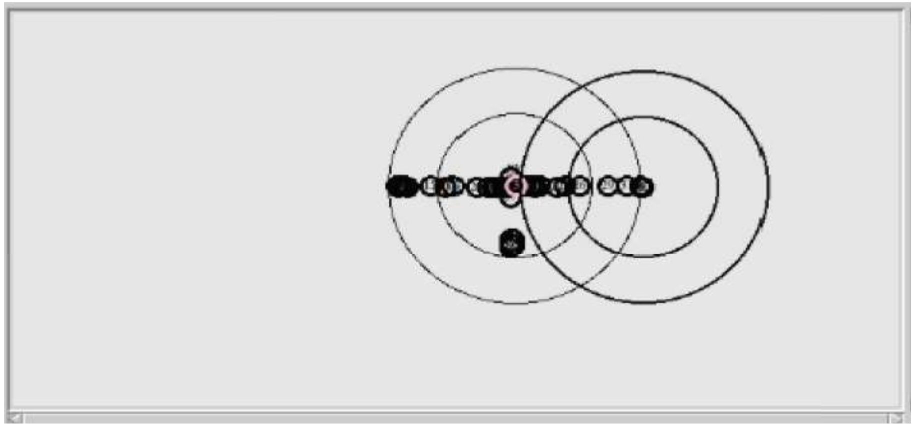

Figure 3: Sample relay node broadcast the message on NS2.

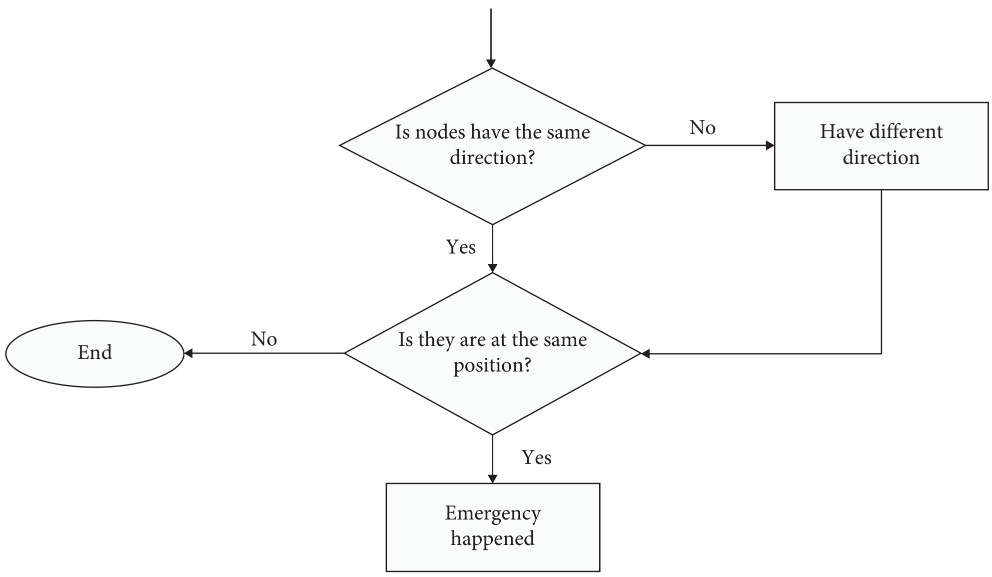

Figure 4: Generating emergency message.

Table 5: Signal strength estimation.

Signal in dBm	Status
−50	Excellent
−60	Very good
−70	Good
−80	Low
−90	Very low
−100	No signal

Pseudocode that used to select relay node is as follows:

1. Source node broadcast emergency message.
2. Nodes check whether the received message was exist or not
3. Receiver node check while they were moving to the emergency place
4. If a received message exists dismiss it
5. Else calculate nodes_ttl
6. If nodes_ttl is the maximum end
7. Else check the density of the nodes concerning neighbor nodes
8. If not dense back to step 7//to recalculate node density
9. Else calculate nodes avr_rss
10. Calculate avr_rss
11. Else rebroadcast the emergency message//relay node is selected

3.5. Scenarios to Select Relay Node. We have prepared the following sample scenario to realize the diagram's logical flow. Our proposed solution was to consider the emergency vehicles on the road at cross-sections by collecting the information from beacon messages. We have focused on selecting a relay node at the crossroad scenario, and we have taken it. Then, it directly applies the proposed solution and selects the best relay node, which will rebroadcast the emergency message later. As indicated in Figure 6, an

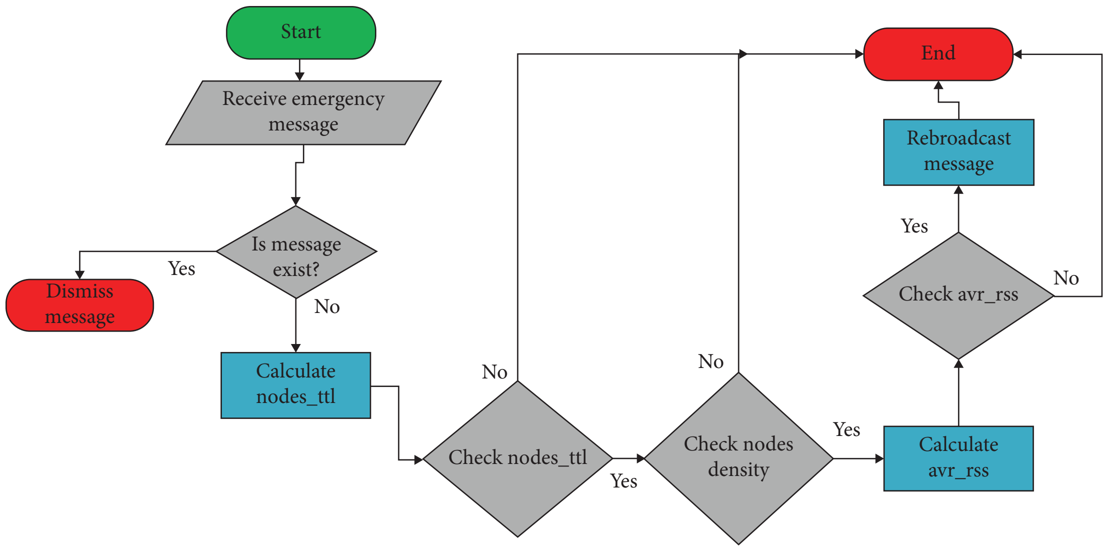

Figure 5: Flow diagram with relay selection.

accident occurred on the road at the center as indicated in red color. The node with red color is the source node that broadcasts the emergency message within circular red, which represents its communication range. Other nodes that are found in the communication range received the message and the proposed solution was applied to them. Then, from the list of vehicles, the vehicles in green were selected as the relay node. The selected relay node will rebroadcast emergency messages to other vehicles traveling to the accident position. Vehicles that are moving to the emergency place were required to be informed since they have the same direction within the accident location. So based on the source node's broadcasting range, an emergency message was disseminated to other vehicles.

In the proposed solution, nodes check their **nodes_ttl, density, and avr_rss** to select reliable relay nodes in urban scenarios. We have described the proposed solution as indicated in Figure 7.

As described in this scenario, when the accident occurred at the cross-section, the source node broadcasted the emergency message as indicated in red color. The nodes within the source node's communication range will receive the message. Then, the green node was selected as the relay node with the proposed solution and rebroadcast the emergency message to its neighbors. The green vehicles are selected from this scenario based on their received signal strength since they handle signal quality and interference. They are also selected due to the source node, which broadcasts the emergency message found in front of them. Additionally, to handle the probability of nodes that can be found at an equal distance from the source node, node density and nodes_ttl were taken. Due to this fact, we have selected the node with avr_rss as the relay node in addition to other parameters.

4. Simulation Tools and Development

To realize our proposed work, we have taken urban scenarios with dense nodes at crossroads. Additionally, we have used network simulation tools to implement the real scenarios. Due to the expense of the equipment and wireless resources, we have used simulation tools rather than directly applying them to our scenario. For simulation purposes, we used NS2 and SUMO tools. In this section, we will describe the tools we have used to design and implement our proposed solution. Realizing the proposed solution is difficult due to its high cost and high labor requirements. Network simulators (NS2) are tools that are used to represent real-world nodes on a single computer by simply writing scripts using Python or C++ programming language. It is also a discrete event NS2 of the internet that is used to create CSMA, wireless, and point-to-point network connectivity within the nodes. It allows nodes to exchange messages among connected devices such as RSU, vehicles, and other wireless devices.

The NS2 also consists of metrics that are used to evaluate the performance of the proposed solution, such as throughput, packet delivered, packet sent, E2E, signal strength, and node information that consists of speed, direction, position, and the like.

The key performance metrics used to evaluate the effectiveness of the proposed SMD algorithm in urban VANETs typically include the following:

PDR: This metric measures the ratio of successfully received packets to the total packets sent by the sender. In the context of the SMD algorithm, a higher PDR indicates better reliability in delivering safety messages despite network dynamics and potential congestion:

$$\mathrm{PDR} = \frac{\text{Packet Received}}{\text{Packet Sent}} \times 100. \tag{2}$$

PLR: The number of packets lost without delivering the receiver nodes. The packet will be lost due to the broadcast storm. As the number of rebroadcasted nodes increases over time, the number of packets lost also increases proportionally. The proposed solution was applied to reduce this and enhance the number of lost packets in-vehicle

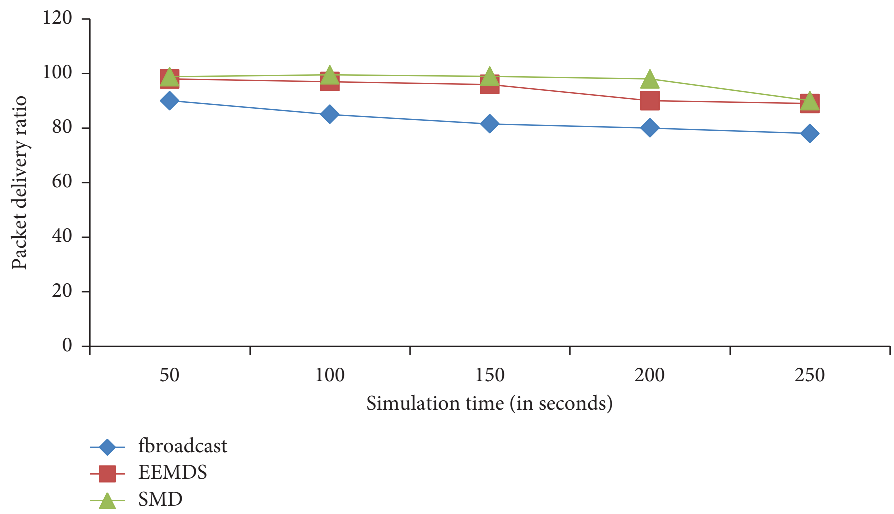

FIGURE 6: Packet delivery ratio for 20 nodes.

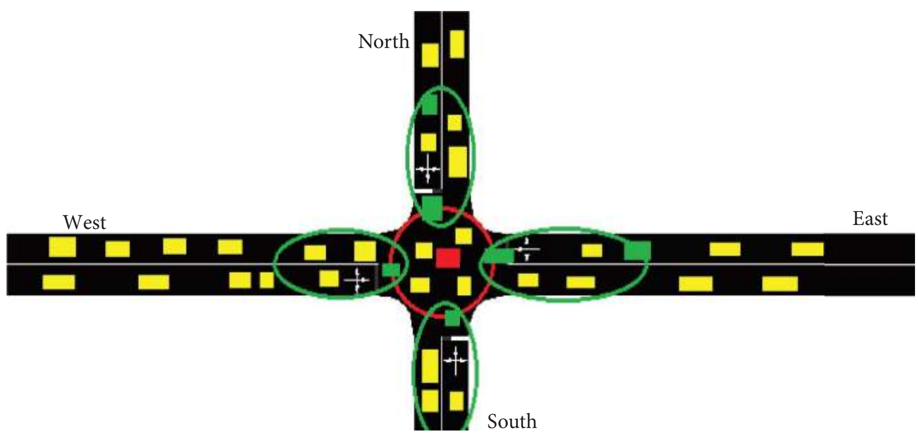

FIGURE 7: Proposed scenario to select relay node.

communication. To calculate the number of lost packets, the difference between sent and received packets:

$$\text{PLR} = \text{Total sent packets} - \text{total received packets}. \quad (3)$$

E2ED: This metric quantifies the average time taken for a packet to travel from the sender to the receiver. Lower E2ED is crucial for real-time safety applications in VANETs, as it ensures timely dissemination and processing of safety messages:

$$\text{E2ED} = \sum_{i=0}^{n} \frac{\text{received} - \text{sent}}{\text{packet} - \text{duration}} \times 1000. \quad (4)$$

Throughput: Throughput measures the rate of successful message delivery over a communication channel. For the SMD algorithm, it reflects the efficiency of message dissemination under varying traffic conditions, indicating how well the algorithm utilizes available network resources:

$$\text{T} = \text{S/t}, \quad (5)$$

where S = total size of successfully received data (in bits) and t = total time taken for the data to be received (in seconds).

4.1. Prototype Implementation. This section will describe the mobility generated with the SUMO and the proposed solution simulated with NS2 tools. Figure 8 shows the steps from the network file as input to the result as output. The real OpenStreetMap equivalent to a real traffic network was taken as (∗.net. XML or ∗.osm) file was taken. Since it is mandatory to convert the real networks to NS2 format, the SUMO tool used to generate node mobility is applied. Many commands are applied at this phase, and the file is ready to apply the proposed solution. After applying the SUMO tool, the traffic network was applied with NS2. At this time, the real scenario is exactly converted to analyze and apply the proposed solution. The real traffic network consists of its specified area, several nodes, appropriate parameters, and start/stop simulations generated throughout the procedure.

In general, the flow of integrating the mobility generator with the NS2 to fulfill the proposed solution is described in Figure 9.

4.1.1. Creating Multidirectional Traffic Road. In this topic, we created a real crossroad scenario using network simulation and mobility-generating tools. Figure 10 shows the

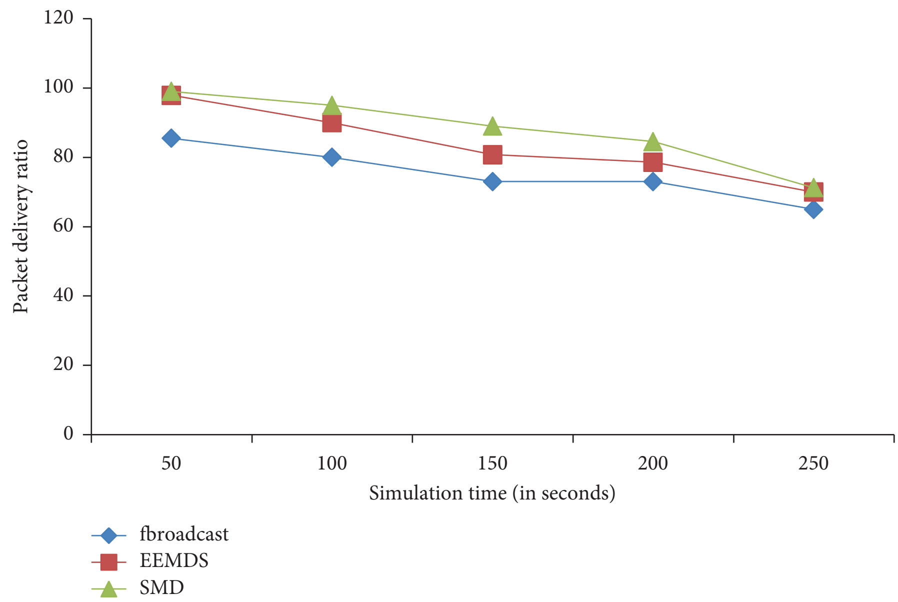

Figure 8: Packet delivery ratio for 60 nodes.

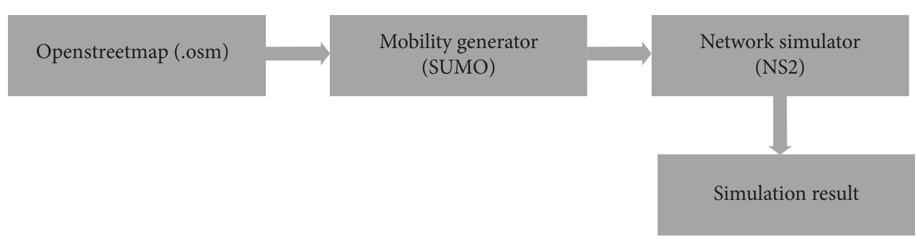

Figure 9: Mobility generator and integrate with NS2.

real scenario which was generated by SUMO tools with NS2. After the installation of sumo tools on our Ubuntu operating system, we have used Net Editor to generate network files for XML configuration as follows:

Step 1: Navigate to the SUMO installation directory and open the “sumo” folder. Inside, open the “bin” subfolder to access the NetEditor tool.

Step 2: Check the connectivity among nodes by selecting them. The color of the nodes will change from red to green to indicate they are connected. After ensuring the nodes and lanes are connected, save the network as a.net.xml file in your designated folder.

Step 3: Generate a routing file by converting the network you created into a route network. Open a terminal in your working directory and run the following command:python randomTrips.py–n Adama.net.xml –r adama.rou.xml –e 100 –l. You can either copy the randomTrips.py file from the sumo/tools folder and paste it into your working directory or provide the full path to this file when running the command. This will generate a route file from the network file created in the previous steps.

Step 4: Generate node mobility and create a SUMO configuration file. Create a file named adama.sumo.cfg that links the network and route files. Once done, save the configuration file as adama.sumo.cfg in your working directory such as

- *<configuration>*
o *<input>*
- *<net-file value = “adama.net.xml”/>*
- *<route-files value = “adama.rou.xml”/>*
- *</input>*
- *</configuration>*

Step 5: To run with SUMO-GUI. Simply type./ SUMO-GUI adama.sumo.cfg by opening the terminal in the working directory. In end, the real scenario was generated as indicated in Figure 10.

Step 6: After this, generate the output file from the sumo configuration file, which consists of beacon information. To do this type sumo –c adama.sumo.cfg --fcd –output sumoTrace.xml command on the terminal window. The beacon information containing the vehicle’s position, speed, lane, and other parameters is stored in float car data (FCD), used as every vehicle’s default value. Now, vehicle mobility is created by following all the above steps, and after this, the sumo file is integrated with the NS2.

Step 7: The command that is used to generate NS2 compatible format from the SUMO file is python traceExporter.py –fcd-input sumoTrace.xml –ns2config-output adama.tcl –ns2activity-output myactivity.tcl –ns2mobility-output mymobility.tcl. Now NS2 which consists of the editable code is generated.

The ∗.tcl files consist of their files where adama.tcl contains many nodes, activity file, mobility file, start/stop time, and floor size; myactivity.tcl consists of SUMO_ID and mymobility.tcl files contain the source and destination position of nodes concerning their time movement.

Step 8: At the end, open adama.tcl with gedit editor from Ubuntu and type some codes such as adamaNam.nam that are used to display nodes animation on NS2.

The below code was added for node animation in adama.tcl file.

```
#setting nam file
set namf [open adamaNam.nam w]
$ns_ namtrace-all-wireless $namf $opt(x) $opt(y)
$opt(x) and $opt(y) represents floor size.
```

After completing these steps, the real traffic mobility scenario is equivalent to the real open street map scenario directly downloaded from Google Maps. Since the integration part is completed, it is possible to analyze the result and simulate the proposed solution in NS2.

4.1.2. Parameters Used in Generated Multidirectional Road Scenario. Parameters can be road traffic or basic safety messages. Various parameters aim to determine the impact of parameters on the broadcast storm. When the simulation time changes to the number of nodes, the level of the broadcast storm will be distinguished. The simulation time concerning several nodes was studied to predict how they impact broadcast storms. The number of nodes that are mentioned as 20, 40, 60, 80, and 100 is randomly generated from SUMO files to measure the amount of broadcast storm with respect to number of nodes. The duration of the simulation is also generated in parallel from SUMO files. The broadcast storm occurred with a high probability when a lot of nodes exchanged messages simultaneously. Additionally, when the simulation time was increased with crowded nodes, broadcast storms also happened with high probability. The duration of a packet sent and received was taken with a fixed time interval of one second (1 s) to broadcast while the simulation took place.

The number of nodes and simulation time significantly affect the PLR in the proposed solution, impacting overall network performance. As the number of nodes increases, the likelihood of packet collisions and network congestion rises, and this can lead to a higher PLR.

Parameters used to establish the connection among nodes, such as V2V communication types that integrate nodes with the help of physical nodes by Phy/Wireless, are also used. When the message is disseminated among nodes, it requires the path it travels. This path is a channel in which the antenna will broadcast. An omnidirectional antenna type was used in our simulation setup. In V2V communication, IEEE802.11p standard is used at the physical and MAC layer due to vehicles using DSRC. The range of communication is 1000 m for maximum and 300 m for smaller range at high speed traveling 200 km/hr [10]. To get accurate information about the nodes such as time and position, they are equipped with GPS. In general, Table 6 presents the summary of the adopted NS2 parameters [26, 27].

5. Result and Discussion

In this section, we have described the results of the proposed solution by comparing it with existing approaches. The simulation takes place by considering the described parameters. The interval for message broadcasting, the rate at which the message was disseminated, and the simulation time were considered in the table above. To measure the performance and realize the parameters used in the listed table, it is needed to display on NS2 animation. It is possible after integrating the sumo-generated traffic road and NS2 network simulation tool. Then, the proposed solution was inserted into the generated scenario. After the completion of these processes, the generated adamaNam.nam file from adama. tcl with the sample of the proposed solution is displayed in Figure 3. In this figure, when an emergency happens at the center of the road, the emergency node (represented in red color) broadcasts the emergency message within its transmission range. When an emergency happens at 27.7 s, node three generates an emergency message. As a sample code, the following three lines are added in adama.tcl file.

When the time is up and the nodes reach the center of the road, these sample codes generate the emergency message:

```
$ns_ at 27.17 "$node_ (3) label EM"
$ns_ at 27.17 "$node_ (3) color red"
$ns_ at 27.17 "[$node_ (3) set ragent_] emergency"
```

The nodes within the source node's transmission range will receive the emergency message. After the proposed solution was applied, node within the green color was selected as a relay node. Then, it will rebroadcast within its transmission range. For relay node selection, the sample of codes was added in adama.tcl file.

```
$ns_ at 27.17 "$node_ (12) label RN"
$ns_ at 27.17 "$node_ (12) color red"
$ns_ at 27.17 "[$node_ (12) set ragent_] relay"
```

After the setup and simulation results were completed, the following performance metric was considered to evaluate whether the proposed solution fits its objective. In this study, we have considered PDR, PLR, and E2ED performance metrics. When these performance metrics were measured, different simulation times and the number of nodes took place. We have considered three network evaluation metrics to compare the proposed solution's performance with other

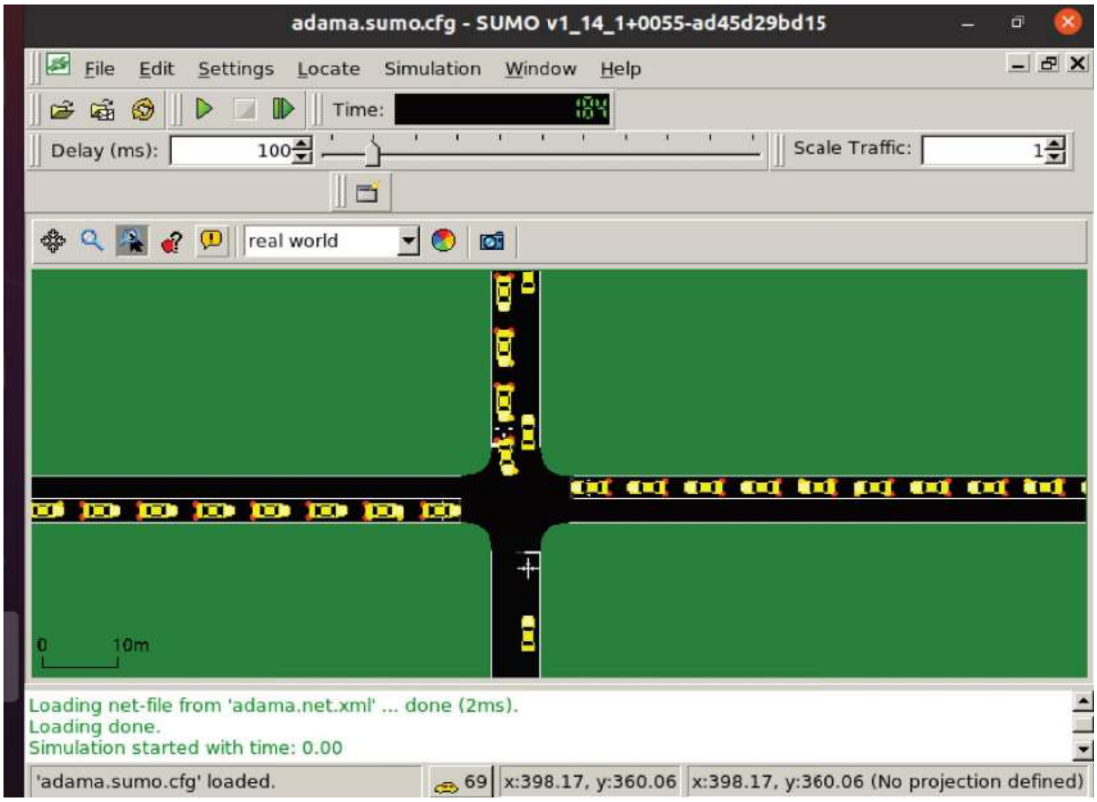

Figure 10: Sample of vehicle mobility in our scenario.

Table 6: Parameters in generated mobility.

Types of parameters	Description	Values
Network simulator	Network simulator 2	NS2.35
Traffic generator	SUMO	Sumo v1_14_1
Propagation type	Two ray ground	Propagation/TwoRayGround
Physical propagation model	Wireless	Phy/WirelessPhy
Antenna type	Omnidirectional antenna	Antenna/OmniAntenna
Communication type	Vehicle to vehicle	V2V
Road traffic	Types of street Area Number of vehicles Speed of vehicles Traffic direction	Crossroad 700×600 20, 40, 60, 80, 100 20 m/s Multidirectional
BSM	Packet size Transmission interval Data rate	128 byte 17–27 s 10 Mbps
Simulation time	Total simulation time	250 S

broadcasting approaches, because metrics play a core role in the broadcasting approach, especially in a broadcast storm. When a packet broadcast storm happens, the number of packets delivered to the target nodes is small due to the storm of packets. Second, this storm increases the number of lost packets. They are dropped without reaching the destination node. Lastly, a delay is a core part of SMD. Hence, a microsecond gap brings unbelievable damage. When nodes are failed to receive information at the right time due to packet loss, E2ED metrics were considered in the study to compare the performance of the proposed solution.

Figure 11 represents the comparison of the proposed solution with the EEMDS [8] and fast broadcasting [10] approach. It describes the effect of node density on the PDR.

In the initial phase when the number of nodes is small, the number of packets delivered to the destination is high in fast broadcasting, EEMDS, and SMD because the number of rebroadcasting nodes is small. At this time, all nodes have received the packet. Even though the number of nodes increases from 20–100, the amount of packet delivery to the destination decreases slowly, inversely proportional to the number of nodes. When the number of nodes is 80, the PDR graph decreases from 90 plus to 80 plus because many nodes rebroadcast the message, and the opportunity for the packet to deliver the destination is less. As rebroadcasting increases, the broadcasting storm will happen, affecting the network's stability for individual nodes. In this case, packets collide and fail to reach the target nodes. Many packets are lost when nodes become too crowded. Due to this fact, the PDR graph declines to the x-axis as the number of nodes increases to a hundred. It determines how node density influences packets to deliver to receiver nodes. However, the proposed solution SMD enhanced the PDR by 4% compared to the fast broadcasting method.

In Figure 6, PDR is also calculated using a variety of simulation times for 20 nodes. When simulation time changed from a short period time to a long period time within the density of the same nodes, the value of PDR also changed. As shown in the figure, PDR decreased when simulation time increased from 50—250. When simulation time increased, the distance between the source and destination nodes increased, which affected the PDR to reach the destination. It indicates that PDR is inversely proportional to simulation time. As simulation time increased, PDR decreased and vice versa. For 20 nodes, different simulation times were taken, and the PDR result was analyzed. When simulation time is around 50 and 100, the PDR is relatively the same, with less difference in EEMDS and SMD, but it is highly varied with fast broadcasting approaches. From the result of 20 nodes, SMD enhanced PDR by 17% compared with broadcast. The proposed SMD algorithm mitigates packet collision and broadcast storm issues through fair message dissemination by leveraging adaptive broadcasting and prioritization techniques. It prioritizes critical safety messages and dynamically adjusts broadcast intervals to current network conditions, effectively reducing redundant transmissions and preventing network congestion.

As described in Figure 8, PDR for 60 nodes with different simulation times is considered. When simulation time is less, PDR is high, and when the simulation time is more, PDR is low. Due to this fact, the graph declines as simulation time increased from low to high. When many nodes send and receive packets for a long time, the probability of a broadcast storm is high. This reality is described in this figure. PDR is high even though nodes are dense at the start time or for a short period; it starts to decline when the simulation time increases. The SMD enhanced PDR by 12% as compared with the fbroadcast approach.

In general, even though node density changed from 20 to 60 with different simulation times, PDR decreased from top to bottom as node density and simulation time increased from left to right. When the simulation time is 50, PDR is high, but when the simulation time is changed to 250, PDR decreases by a high percentage. From this, we can conclude that both node density and simulation time have an impact on PDR. However, SMD enhanced PDR by 17.5% on average for 20 and 60 nodes at different simulation times.

As described in Figure 12, as the number of nodes increases, the number of lost packets increases proportionally. When the number of nodes is small, the opportunity for lost packets is also small in three of the approaches. This is due to fewer rebroadcasting and broadcasting storms. However, as the number of rebroadcasts increases concerning many nodes, broadcast storms happen with a high percentage, which results in a high PLR. SMD selects a qualified node from the lists and has minimized the number of lost packets with nearly less than 5% as compared with fbroadcast and EEMDS approaches.

When simulation time is applied to a specified node density with constant and varying PLRs, changes are observed. As described in Figure 13, when simulation time increased from 50 to 250 for 20 nodes, PLR also increased by a high proportion. In SMD and EEMDS approaches when simulation time is around (50–100), they have enhanced the amount of loss packets with high probability compared with fast broadcasting. The reason behind is the two approaches follow minimized rebroadcasts while in fast broadcasting all receiver's rebroadcast the packet that form packet flooding. At 150 s, the PLR increased with high probability, and the graph inclined to vertical which indicates the increase of PLR in all approaches. SMD enhanced PLR for 20 nodes with nearly less than 3% as compared with fbroadcast and EEMDS.

For 60 nodes, PLR is also described in Figure 14. As node density changed from 20 to 60, PRL also changed with respect to number of nodes. When simulation time increased, PLR increased, but their difference is the value of data loss. From 50 to 250, the graph inclined up, which indicates the increase of PLR concerning simulation time. For 60 nodes, SMD enhanced PLR by 5%, as described in Figure 15.

To summarize the PLR concerning simulation time and node density, it is directly proportional to the metrics. When the number of nodes and simulation times increases, PLR also increases in proportion. This is due to the increase in the number of rebroadcasting nodes, from a single to many. When many nodes rebroadcast, broadcast storms appear with high probability; in a case, SMD has to try to enhance it. SMD enhanced PLR by 4% on average for 20 and 60 nodes with different simulation times.

By using this equation, E2ED is calculated concerning node density. As described in Figure 15, the nodes' density impacts E2ED in the transmission of the message. The delay is nearly very small when the number of nodes is small.

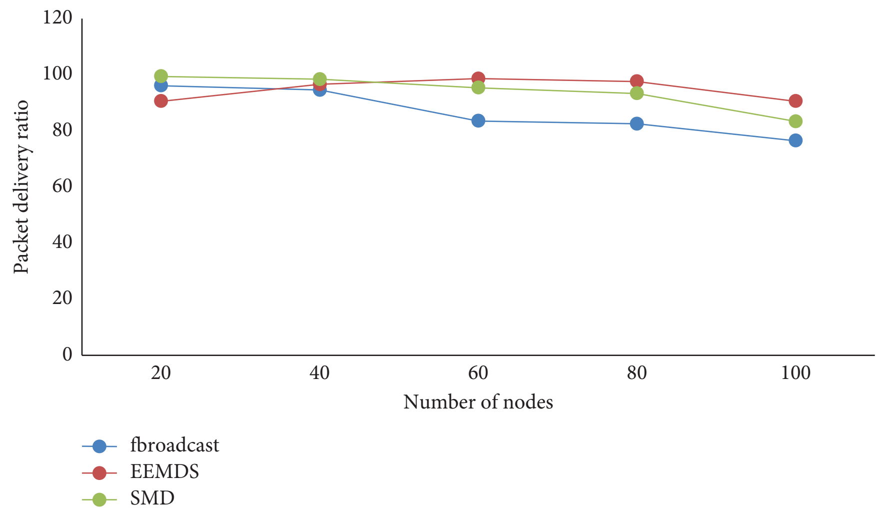

Figure 11: Packet delivery ratio vs. node numbers.

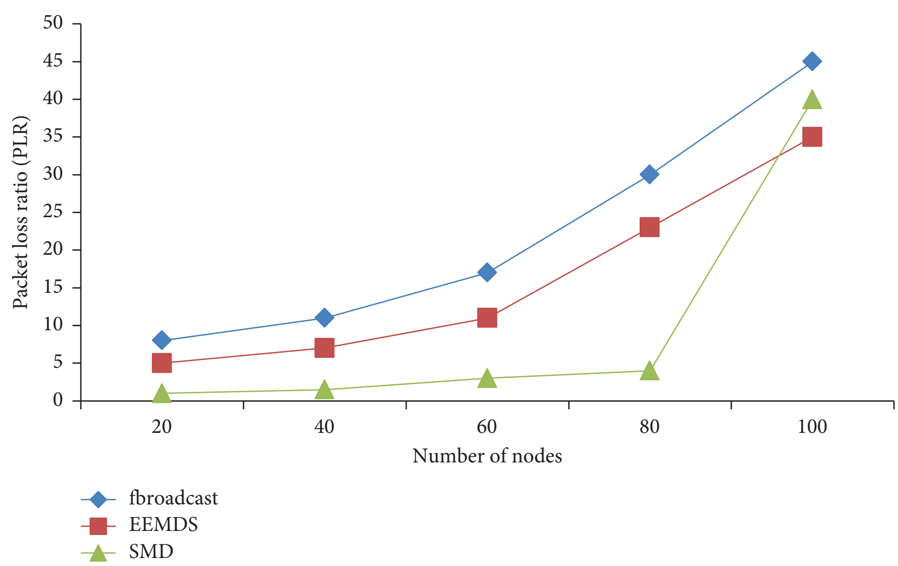

Figure 12: Packet loss ratio vs. node numbers.

However, as the number of nodes slowly increased from left to right, as indicated on the graph, E2ED also increased in parallel. When the number of nodes reaches around a hundred, the delay extremely increased. However, SMD enhanced from above 200% to below 150%. Almost, when the number of nodes is less than 100, SMD enhanced 70% of the fast broadcasting and EEMDS approach. It indicates that the number of broadcast storms that affect the time of transmission was enhanced in a good manner.

In Figure 16, when the simulation times were changed, the result of E2ED is also changed. That means besides nodes' density, simulation time can affect the result of E2ED. When simulation time is changed from 50 to 250, E2ED increases proportionately. This means that when nodes exchange messages in less time, E2ED has a small result, nearly 0.5%. When simulation time reaches 150, the E2ED increases by a high proportion from 1 to 1.90. E2ED has a direct proportion with simulation time.

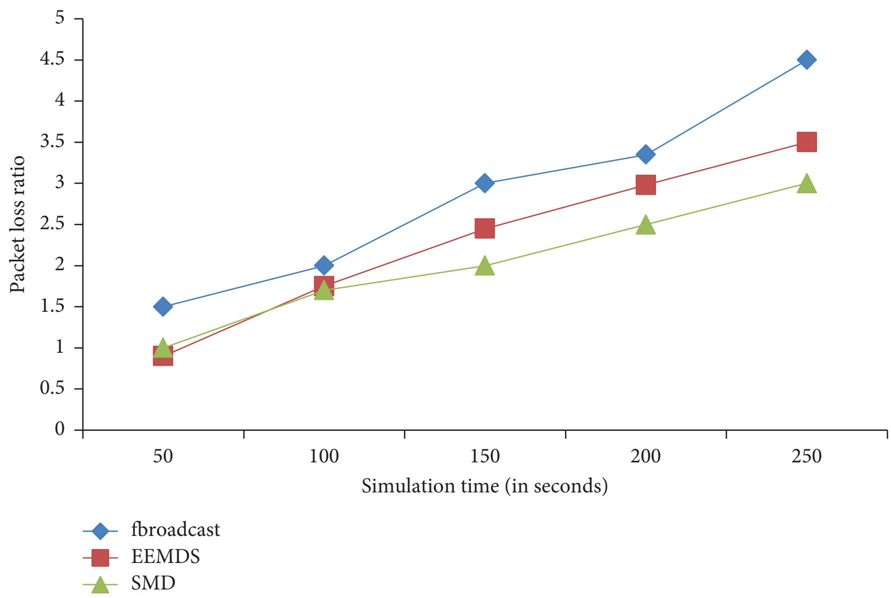

Figure 13: Packet loss ratio for 20 nodes.

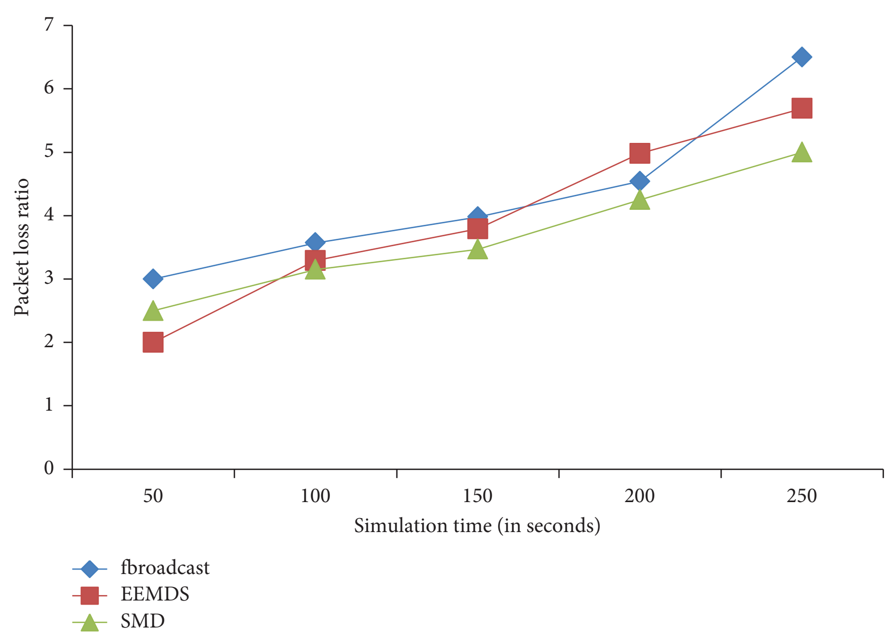

Figure 14: Packet loss ratio for 60 nodes.

When the time increases, the nodes within the transmission range rebroadcast the message while others leave the transmission range. This indicates that, for a small number of nodes as simulation time increased extremely, E2ED also increased in proportion. Even if E2ED increased in all approaches as simulation time increased, SMD enhanced it by nearly 0.75%.

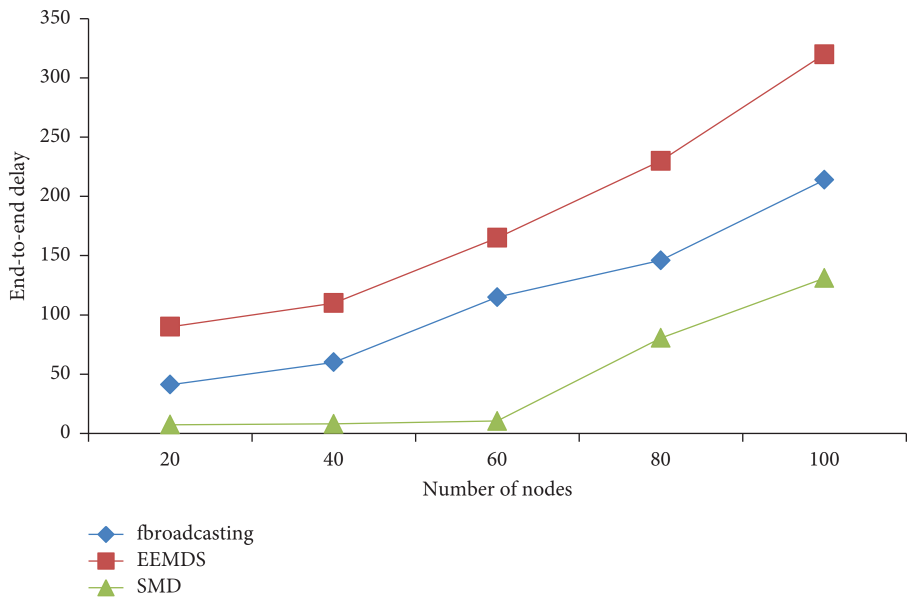

Figure 15: End-to-end delay vs. node numbers.

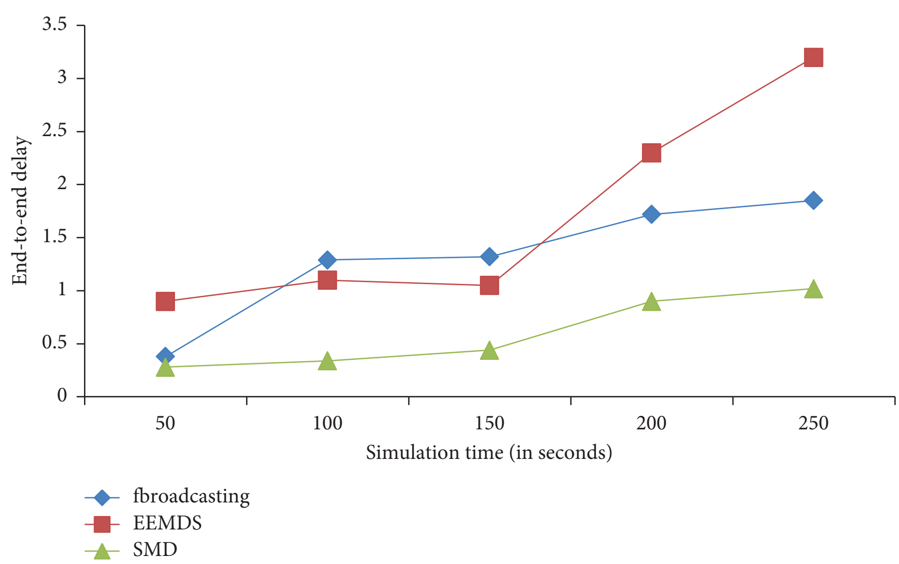

Figure 16: End-to-end delays for 20 nodes.

In Figure 17, for sixty nodes' E2ED concerning simulation time is also compared to measure how simulation time influences delay in message dissemination. As described in the figure, at the initial time, E2ED is increasing simultaneously in broadcast while both SMD and EEMDS have relatively improved with less than 0.4% until simulation time reaches hundred seconds. When simulation is over a hundred seconds, EEMDS increased with high probability because many nodes rebroadcast the message. However, SMD enhanced it by nearly 0.58% as displayed in the figure.

From Figures 15, 16, 17 of E2ED, it is possible to conclude that as the number of nodes changed from twenty to sixty and simulation time increased; E2ED also increased proportionally. The number of nodes and simulation time

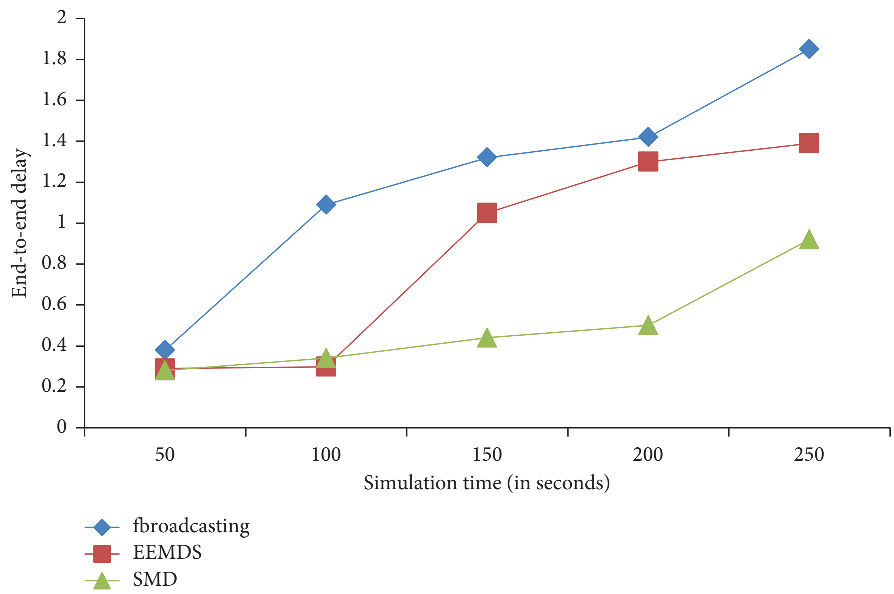

Figure 17: End-to-end delays for 60 nodes.

metrics have affected E2ED results in SMD, EEMDS, and fbroadcast. However, SMD enhanced E2ED by 0.54% on average for 20 and 60 nodes at different simulation times.

6. Conclusion

This study addressed the issues caused by numerous rebroadcast nodes within a specified transmission range. The proposed SMD algorithm selects a single relay node to minimize the number of rebroadcasts. This approach enhanced the packet collision and broadcast storm probability by selecting a single rebroadcast node within a specified transmission range. To realize the proposed solution, network simulation tool NS2 and traffic generators SUMO were used for implementing and generating multidirectional traffic roads. From the implementation, the generated results are discussed in graphical form to compare and measure the performance of the proposed solution. The SMD has shown better performance metrics compared to fast broadcasting and EEMDS. It has increased the PDR by 4%, reduced the PLR by 5%, and decreased the E2ED by 0.5%.

Data Availability Statement

For this type of research, the data sets used and/or analyzed during the current study are included within the article and can be further accessed from the following repository: https://repository.ju.edu.et/handle/123456789/7606?show=full. No additional data are required to be reported.

Ethics Statement

All procedures performed in the studies were in accordance with the ethical standards of the institutional and/or national research committee and with the comparable ethical standards.

Consent

Formal consent is not required for this type of study. Authors gave consent for the publication of the research article in Security and Communication Networks.

Conflicts of Interest

The authors declare no conflicts of interest.

Funding

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Acknowledgment

The authors would like to express their sincere gratitude to Jimma University, specifically the Jimma Institute of Technology, for providing excellent facilities. The support and resources made available greatly contributed to the success of this work. The authors are deeply appreciative of the conducive research environment. The authors also thank the staff for their invaluable assistance. Without their support, this research would not have been possible. The data are available at the following website: https://repository.ju.edu.et/handle/123456789/7606?show=full.

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