A Reliable Message Broadcast Protocol Using Active RFID Mechanism in Vehicular Ad hoc Networks

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***Abstract*—One of the crucial areas of research in vehicular ad hoc networks is message broadcasting. The reliability of connections, which depends on a variety of factors including delay, packet delivery ratio, and throughput, is one of the challenges this area presents. The transmission of messages is very important since the topology of the Vehicular Ad hoc Network (VANET) changes so often, which causes data loss. Therefore, it is essential to create communication protocols and improve message broadcasting techniques in VANET in order to prevent additional emergencies and hazardous situations. The position of on road vehicles, which is mostly dependent on the positioning system's accuracy, has an impact on the effectiveness of message broadcast protocols based on location in vehicular ad hoc networks. Furthermore, GPS-based dissemination protocols have numerous challenges because of their high energy consumption, poor accuracy, and dependence on updated maps for real-time automated applications. In this paper, a Reliable Message Broadcast Protocol (RMBP) which is based on active radio frequency identification technology, is presented to decrease GPS-based issues and enhance message broadcasting efficiency by increasing the positioning system's accuracy. In this approach, the route is partitioned using embedded active Radio Frequency Identification (RFID) tags to provide a location-based method. In RMBP, a vehicle receives information about its location by traversing the tags and transmitting a beacon immediately to its neighbors. Additionally, this protocol incorporates the selection of a relay vehicle that chooses the farthest neighboring node based on the received beacons. The simulation results conducted in the NS-3 application have proven the efficiency of the proposed protocol in terms of delay, packet delivery ratio and throughput.**

***Keywords*—Vehicular Ad hoc Network (VANET), message broadcasting, Active Radio Frequency Identification (ARFID), Radio Frequency Identification (RFID)**

I. INTRODUCTION

One of the essential aspects of road safety is Vehicular Ad hoc Network (VANET) which is an evolving field in intelligent transport systems. In a self-organizing, infrastructure-less ad hoc network, broadcasting is a fundamental communication operation. While ensuring passenger comfort and safety, the VANET's implementation faces issues related to traffic, network congestion, delays, etc.

The main purpose of Intelligent Transportation Systems (ITS) that attempt to lessen traffic accidents is generally to improve human health and wellbeing. The event-based safety applications utilize wireless vehicle-to-vehicle communications to warn drivers of hazardous circumstances [1]. The deployment of a single-hop system is necessary for the distribution of messages as well as protection of crucial and risky locations because the coverage of Dedicated Short-Range Communication (DSRC), which relies on the 802.11p, is limited [2]. Emergency messages must be broadcast right away since delays in their dissemination could create a dreadful disaster. The general organization of the VANET is shown in Fig. 1.

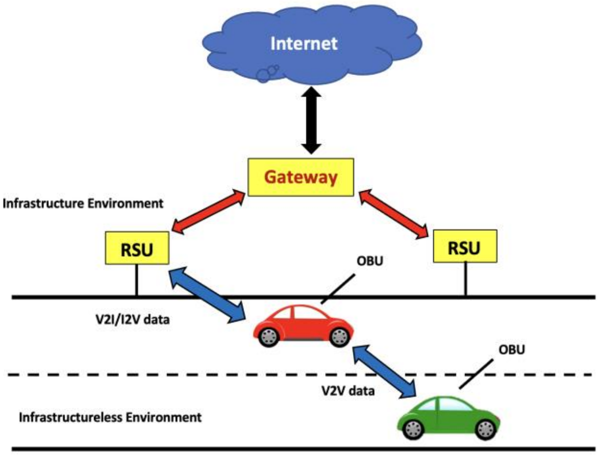

Fig. 1. Overview of VANETs.

In general, selecting the neighbor which is far away from the relay node reduces the count of nodes necessary in emission cycle. Also, using positioning systems like the

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Global Positioning System (GPS) and its derivations is important to find each vehicle's geographic location in order to identify the neighbor that is the farthest [3]. The location of vehicles in a simulation environment may also be quickly and accurately determined by network simulators with extensive facilities. But an error in location and the transmission of incorrect data to another vehicle can lead to unsuitable forwarder vehicle selection and, as a result, decreases the quality of service in network [4–6].

Radio Frequency Identification (RFID) technology is essential in fast-paced, dynamic environments like VANETs [7]. It enables real-time tracking and precise location identification of vehicles, enhancing safety, emergency response, and traffic management. RFID reduces human intervention, promoting accuracy and efficiency, making it a vital tool for modern transportation systems.

Passive RFIDs may be deployed to identify vehicles but they are least effective when the vehicles are far away [8]. Hence, the deployment of active RFIDs to identify vehicles at long distances facilitates and improves broadcasting. Also, the choice of the relay node may be made more quickly, which will eventually increase the rate at which vehicles exchange beacons.

In this paper, a Reliable Message Broadcast Protocol (RMBP) which is based on Active Radio Frequency Identification (ARFID) technology is presented, which would allow embedded positioning systems to give VANETs the idea of location awareness while get rid of the problems of GPS positioning. The objectives of this work can be summed up as follows:

- Presenting a system that uses active RFID tags placed in rows on the road instead of GPS to accurately and quickly locate vehicles.
- Arranging RFID tags effectively to prevent coverage gaps from occurring on the route.
- Designing a proactive strategy that is effective for deciding which relay node to use to convey emergency messages based on locating the farthest neighboring vehicle.
- The transmission of emergency messages using broadcasting rules to ensure message delivery reliability.
- Validating contribution of RMBP in view of delay, packet delivery ratio, and throughput.

The remaining part of this paper is divided into the following sections: A discussion of related works is provided in Section II. Section III explains the specifics of the RMBP protocol and how it operates. Section IV offers simulated scenarios and evaluates the outcomes of the simulation. Section V compares and contrasts the RMBP with the corresponding protocols. The paper concludes in Section VI.

II. Literature Review

Zhang *et al.* [1] proposed an effective, non-deterministic cooperation mechanism that maximizes assumed broadcast performance by choosing co-operators with the highest assumed Single-hop Broadcast Efficiency (SBE) value for a relay and setting up the cooperative broadcasting process when the assumed SBE value is greater than that of a one relay dependent broadcasting mechanism. This method is suitable for smaller set of nodes but cannot be implemented efficiently for large collection of nodes.

Wang *et al.* [2] proposed a certificateless-based anonymous and revocable authentication mechanism for vehicle-to-vehicle interactions. This approach overcomes the drawback of routine Identity Revocation List (IRL) checks and also lowers the cost in transmission along with authentication of messages by separating the identified related process of authentication from the traffic related message confirmation. However, there is a considerable delay in the broadcasting of messages which needs to be addressed as a research gap.

Ateeq *et al*. [3] discussed and analyzed different routing mechanisms in terms of delay, Position aware Dynamic Routing (PDR), and throughput. According to the authors, a reliable strategy is required to enhance the packet delivery ratio and throughput of message broadcasting and at the same time minimizing the delay. This can be done by implementing the usage of active RFID mechanism along with message broadcasting.

Zhong *et al.* [4] presented a novel Broadcast strategy that, for the first time in VANETs, employs Identity-Based Broadcast Encryption (IBBE) technology, which is a safe data sharing technique appropriate for the vehicle to infrastructure connection. The authors claim that the TA can provide a fixed length of ciphertext for a collection of vehicles using just one encryption. The TA can give encryption responsibilities to the proxy server when new vehicles later seek a service.

Zhang *et al.* [5] suggested an innovative gigabit message delivery technique termed P2MP in a multi-hop mmWave/Dedicated Short Range Communications (DSRC) Vehicle-to-Vehicle (V2V) network for a highway scenario. However, this protocol works well when the communication range is short but at the same time suffers during long range communication.

Han *et al.* [6] proposed a Speed and Position aware Dynamic Routing (SPDR) for the distribution of messages in VANETs. To enable a dynamic hop to hop retransmission of the message, the authors develop a speed measured dynamic greedy routing. The disadvantage of this approach is its multi hop nature which requires a number of nodes to establish communication between the vehicles.

Othman *et al.* [7] proposed a physically safe privacy-preserving message authentication technique utilizing Physical Unclonable Function (PUF), Secret Sharing. The authors claim that even in the case of memory leaking, this protocol provides security against passive as well as active assaults. However, the protocol can be strengthened by integrating with different machine learning algorithms.

Bhatia *et al*. [8] presented an adaptive broadcast interval for data dissemination for an Infrastructure-to-Vehicle (I2V) environment. According to the authors, the roadside units broadcast the information to the nodes after a stipulated transmission time gap. The authors have used the Software-Defined Network (SDN) architecture having OpenFlow-enabled Restricted Stock Units (RSUs) and SDN controllers. The drawback of this approach is that the road side units consume a lot of energy for the communication of messages which needs to be addressed as a research gap.

Liu *et al.* [9] presented devising Medium Access Control (MAC) schemes that assured transmission of data within a specified delay. They have considered a multiple channel single hop ad hoc network model in which every node holds packets to transmit to other nodes. The disadvantage of this method is that nodes cannot able to hold the data for a long period of time which results in lossy data.

Ma *et al*. [10] presented an efficient SINR-based model for the purpose of analyzing the Quality of Service (QoS) of IEEE 802.11p/bd-driven VANETs for safety applications. Given broad channel fading models and general node shape distributions, the authors have designed a unique concept for determining the distribution of Signal to Interference to Noise Ratio (SINR) on every node in the VANET. However, this approach suffers with a constant noise during the broadcasting process.

Afrashteh *et al*. [11] presented a Route Segmented Broadcast Protocol based on the Radio Frequency Identification (RFID) technology (RSBP-RF) in which an embedded location system gives position awareness for VANETs and eliminate challenges with GPS-based positioning and increases the reliability of message broadcasting. This approach uses embedded RFID passive tags to segment the path and aids in delivering location aware technology. However, this approach suffered with a problem of implementing multiple hops which makes this method complex.

Seliem *et al*. [12] has analytically determined the probability distribution of the vehicle-to-drone packet delay on a bi-directional roadway. The model used in this approach takes into account both the cluster length and the wireless communication range of the vehicles. However, to establish effective communication, the length of the cluster must be predetermined which creates overhead.

According to the geographic knowledge and the surrounding traffic situation, Qiu *et al*. [13] presented new techniques for choosing parked automobiles as relays/RSUs. Benefits include a considerable decrease in the implementation of RSUs and an increased connectivity. However, they suffered with a drawback of unreliable connection in relay nodes.

In addition to discussing other proposed methodologies based on the Intelligent Transportation Systems (ITS), Internet of Things (IoT), Priority messaging, Clustering approach, Software Defined Network (SDN), and Fog Computing, Ghazi *et al.* [14] analyzed some new contributions to message broadcasting in VANET. The contributions such as energy efficiency, multi hop communication are important for effective message broadcasting but at the same time cannot provide reliable communication because of network interruptions.

Zhang *et al.* [15] presented a hybrid Medium Access Control (MAC) protocol for Basic Safety Message (BSM) distribution based on the Dedicated Short-Range Communication (DSRC) architecture. Its partially dispersed and centralized characteristics can efficiently reduce collisions while maintaining IEEE 802.11p compatibility.

Ullah *et al.* [16] presented message delivery strategies based on VANET congestion prevention scenarios and vehicle Fog computing. The authors investigate a Fog based VANET architecture that can effectively handle message congestion circumstances. The authors have also noted that using Fog servers instead of directly accessing clouds for all queries in connection with massive data repositories helps to decrease accessibility delays and congestion.

In order to increase the message delivery ratio with the fewest feasible hops and delays, Li *et al.* [17] devised the reinforcement-learning-based hierarchical protocol known as QGrid. The authors claim that the protocol operates on two levels. The next most advantageous grid towards the goal is found once the geographical region has been divided into smaller grids. Second, it finds a vehicle inside or heading towards the following grid that is best for relaying messages.

Shah *et al*. [18] proposed a time barrier mechanism as a method of data distribution to lessen the number of messages that might jam the network. The notion of a parent node to distribute the messages in a timely order forms the basis of the suggested solution. The authors claim that the time limited approach is updated to address this complaint in order to avoid superfluous broadcast, which can lead to the broadcast storm problem.

Xiong *et al*. [19] proposed a method that increases the resilience and accuracy of CP navigation systems while guaranteeing the overall positioning performance of many vehicles in a hybrid navigation situation. This method can be used to detect the location of the nodes but cannot be implemented in case of long-distance nodes.

Benkerdagh *et al*. [20] proposed a novel approach for processing data before the distribution process as the first stage of the plan. The first message is optimized in this stage to cut down on the number of packets being exchanged. However, this technique cannot be used for large set of vehicle nodes.

For vehicular networks with little signaling overhead, an improved multiple hop-based transmission protocol known as Trinary Partitioned Black-Burst based Broadcast Protocol (3P3B-DTN) have been developed [21]. Three techniques are included in this protocol: the priority Mini-DIFS scheme for time-sensitive messages, rapid channel utilization to lessen congestion, and the trinary strategy to choose a single carry node and lessen the negative based jitter. Additionally, the 3P3B-DTN uses store carry forward technique, in which beacons are saved, transported, and then rerouted by the vehicle nodes if a suitable link is identified, in order to increase the PDR. The drawback of this method is the existence of negative jitter which can be addressed as a research gap in the future.

To address the reliability and latency challenges, Zeng *et al*. [22] have presented a novel probability-based multi-hop broadcast protocol. The authors propose, in contrast to the existing probability-based methodologies, to provide a larger the likelihood of transmission to the nodes that are node's index number and other parameters to determine how far it is from the source node. The probability of the nodes can be determined if the nodes are at located at a nearby distance. This methodology cannot be used for the long-distance nodes.

Bi *et al.* [23] suggested the Urban Multi-hop Broadcast Protocol (UMBP) as a method for choosing forwarder nodes. To choose distant neighboring nodes, this protocol employs iterative partition, mini-slot, and black-burst as well as taking into account urban road structure, competing channels and redundancy of messages. According to the location of the message transmitter and taking into account different broadcasting techniques, such as bidirectional, multidirectional, and directional communication. This protocol can be used only in urban environment and cannot be deployed on highway scenarios.

III. The Proposed RMBP Protocol

This section discusses the RMBP protocol, which is a collection of rules, standards and it has been integrated with an active RFID mechanism for location detection. This protocol works by dividing the road into sections using active RFID tags, is suggested as a position-aware technique. Although passive RFIDs may be used to identify vehicles, they are ineffective when the vehicles are far away [24]. Therefore, the use of active RFIDs to identify vehicles at greater distances facilitates and improves broadcasting. Additionally, the selection of the relay node may be made more quickly, which will ultimately speed up the transmission of beacons between vehicles and introduce the idea of the Reliable Message Broadcast Protocol (RMBP) based on active RFID mechanism.

The key elements of the Proposed RMBP model are mentioned below:

- Communication rules

Beacon-based communication: RMBP utilizes beacon messages for communication between vehicles. Beacons contain essential information such as the sender's identity, location, and message details.

Neighbor discovery: Vehicles use beacons to discover neighboring vehicles and establish communication links for message dissemination.

- Message formats

Beacon format: Beacons consist of structured data formats, including sender ID, timestamp, location information, message type, and additional metadata relevant to the protocol's objectives.

Message structure: The actual message within a beacon follows a predefined structure based on the application requirements, ensuring standardized communication.

- Data exchange procedures

Beacon exchange: Vehicles periodically broadcast beacons to share their information with neighboring vehicles.

Relay mechanism: RMBP defines a relay mechanism to efficiently forward messages to distant nodes. The relay vehicle is selected based on beacon reception and analysis.

- Specific standards

IEEE 802.11p: RMBP can adhere to IEEE 802.11p, a standard for Wireless Access in Vehicular Environments (WAVE), ensuring compatibility and interoperability with VANET communication protocols.

Addressing beacon propagation and concealed nodes is crucial [25]. The proposed protocol utilizes active RFID technology and strategically placed RFID tags to optimize beacon dissemination, ensuring timely and efficient communication. To tackle concealed nodes, The relay vehicle selection mechanism is employed based on received beacons to bridge the communication gap effectively (see Fig. 2).

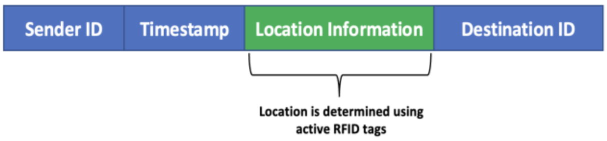


Fig. 2. Beacon structure.

A number of countermeasures might be used to lessen the effect of metal items on the suggested procedure. The use of signal processing techniques to lessen the effects of interference, the use of alternative localization technologies that are less susceptible to interference from metallic objects (like GPS or inertial sensors), or the design of the protocol with reliable error correction and fault tolerance mechanisms for handling communication disruptions can be implemented effectively [26–28].

A. Network Model

Each vehicle in the RMBP protocol comes equipped with two types of IEEE 802.11p-compatible wireless equipment, one of which is used for disseminating messages and the other for broadcasting beacons [29, 30]. In the proposed network concept, active RFID tags that record relative location data are also implanted on the route. The tags are arranged across the road in pairs of rows with a fixed spacing between the rows. In order to interact with the tags, an RFID reader needs also be installed close to the road surface in the vehicle control center [31]. The route is divided into parts by the embedded tags, with each segment's length being equal to the broadcast range of the vehicle nodes. Each part is further separated into two sub parts, each of which has pair of cells. Additionally, each vehicle stores the information that it has received from its one hop and two hop neighbors [32–34]. The vehicle then checks its available table by using the information from the beacons it has received, classifying any associations as single step neighbor information and any latest information that has not yet been added to its table as a multi-step neighbor information.

Time-Interval Driving Method (TISM) is used in the network model to determine the minimum safety distance from a node and the node in front of it. Two seconds are considered in the RMBP protocol as a safe distance between two succeeding cars [35]. Therefore, the allocation of cars in each queue has been carried out in accordance with Eq. (1) in order to comply with the law mentioned earlier.

$$n = n1 + n2 + n3 + \cdots + nk$$
$$n = \text{total number of vehicles}$$

where $n1, n2, nk$ are number of nodes.

$$N_j = \left\{ i \in Z^0 \mid 0 \leq \left(\left\lceil \frac{Z_{avg}}{S} \right\rceil \cdot i \right) \cdot D \leq I_{seg} \right\}, j = 1,2,3, \ldots \quad (1)$$

where N_j, I_{seg}, S, D, and Z_{avg} stand for the collection of vehicles in partition j with fixed latitudinal separation, length of the segment, vehicle node speed, safety distance between adjacent vehicle nodes and average vehicle node speed. Generally speaking, $n = n_1 + n_2 + n_3 + \ldots + n_k$ is the total count of vehicle nodes in a stretch with k partition lanes. It should be mentioned that time interval completely relies on a number of factors, including vehicle's weight, the current weather, the state of the road, and the amount of traffic [36]. In this method, the appropriate distance is determined by the amount of traffic, the state of the roads, and the posted speed limit.

In the existing model, if the two vehicles need to communicate with each other, they must be near to each other in terms of distance as long as they are using passive RFID tags [37, 38]. Once their distance increases, passive tags cannot be used for location detection which leads to a broadcast problem. Furthermore, many relay vehicles such as Hop-1, Hop-2 are required to forward the information to the destination as shown in Fig. 3.

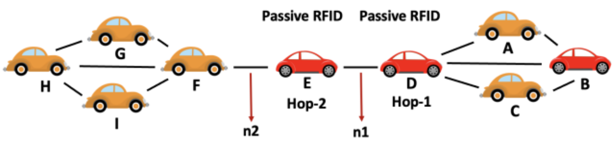


Fig. 3. Existing model based on RSBF-RP protocol.

In the proposed model, this problem is resolved by the use of active RFID tags which can be used to establish communication by selecting the vehicle as the furthest relay vehicle even if they are at longer distances as shown in Fig. 4. The implementation of active RFID tags will decrease the number of hops required.

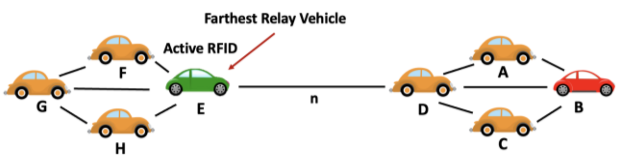


Fig. 4. The proposed RMBP model.

Every vehicle is expected to have the similar communication range, and this model may be applied to one directional highways without the necessity for any road assist equipment. The RMBP protocol is totally dependent on the private network resources as shown in Fig. 4, as opposed to network system like GPS [39].

B. Nodes Placement

For positioning RFID-based vehicles, the RMBP considers three steps, which are handled as follows: placing active RFID tags, reading of tag information, and exchanging information with neighbors. Also, the relative position of the tags and vehicles can be obtained based on the accuracy of the location. If the accuracy of the vehicle's location is high then the message is broadcasted else the next location-based vehicle will be selected as the relay vehicle.

1) Tags placement

RFID readers must be mounted on vehicles in order to scan tags placed on the road for the purpose of gathering environmental data [40]. At each signaling point, there are a number of active RFID tags that make up the RFID infrastructure. As a result, the tags must include information about the location (such as a speed restriction or a potentially hazardous bend). In general, limiting collision, preventing the establishment of coverage holes, and decreasing the rate of overlap are all facilitated by grouping tags together. In order to prevent interference, tags are spaced away from one another as illustrated in Fig. 5 with a constant distance (*vd*, *hd*, *dd*). Similarly, using two rows of tags assures that they will be read while passing vehicles. Along the middle of the guard zones, the second-row tags are positioned prior to the front row. Half the typical vehicle width ($w/2$) is used to calculate the distance between the road's edge and the marginal tags. There won't be any coverage gaps as a result, and if a vehicle passes through the front row tags holes, its reader will certainly connect with the next row tags. RFID tag spacing can vary optimally based on several factors such as RFID technology, frequency of operation, deployment environment, and intended read range [41]. The proposed spacing rule was aimed at minimizing signal interference by maintaining a minimum distance of four times the radius of the coverage area between tags.

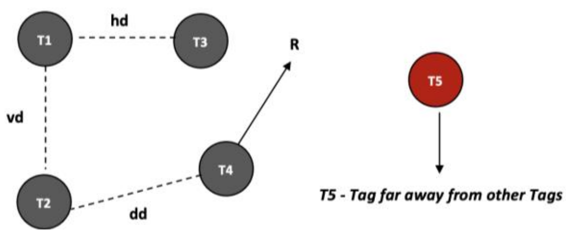


Fig. 5. The placement of active tags.

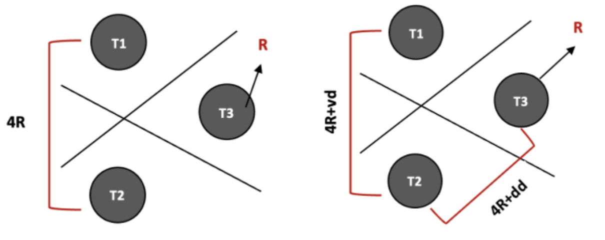
As shown in Fig. 6(a), to lower the overlapping rate, the minimal distance between two neighbor tags can be increased to more than 4R. Similarly, in order to confirm that readers in all vehicle nodes can interact with all the tags, two tags in the same row should be spaced apart by no more than ($4R+vd$) as shown in Fig. 6(b), and the two tags in the adjacent row must be spaced apart by less than ($4R+hd$). Assume that R represents tag radius which is the communication range or coverage area of the active RFID tags, *vd*, *hd*, and *dd* can be computed by Eqs. (2)–(4) as shown below.

$$vd > 0 \geq \left(\frac{2\sqrt{3}}{3} - 2\right) R \quad (2)$$

$$hd > 0 \geq \left(\frac{2\sqrt{3}}{3} - 2\right) R \quad (3)$$

$$0 < dd \leq \left(\sqrt{\frac{15}{3}}\right) R \quad (4)$$

where
vd is the vertical distance between the active tags.
hd is the horizontal distance between the active tags.
dd is the diagonal distance between the active tags.



(a) (b)

Fig. 6. The Distance between nearby tags. (a) The lowest criteria to prevent overlaying. (b) The highest criteria to prevent reading breakdown.

2) Reading tags information

The built-in reader serves as a query engine for the RMBP protocol, occasionally sending out discovery signals through radio waves [42]. If the signals from the reader and the implanted tags clash, the tags antenna creates a magnetic field. The effect of magnetic field can be handled by implementing additional active RFID readers or antennas strategically to improve signal coverage and also to mitigate interference effects as shown in Fig. 7. As soon as a link is made, the tag sends the reader the data stored in its memory. The On Board Unit (OBU), which updates the available location as soon as the connection is established and communicates it to nearby vehicle nodes by receiving the messages.

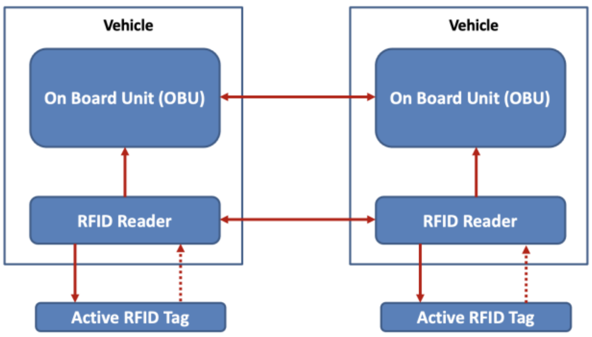


Fig. 7. The RMBP protocol architecture.

Active RFID tags are strategically placed along vehicle routes and act as information carriers. When a vehicle equipped with an RFID reader passes by these tags, the RFID reader emits a signal, powering the RFID tag. The tag then transmits information, including its ID and location, to the reader. This precise location data obtained from active RFID tags improves the accuracy of the positioning system.

Using this accurate location information, each vehicle transmits a beacon to its neighboring vehicles, containing crucial data. The RMBP protocol selects a relay vehicle based on these beacons, choosing one that can efficiently disseminate the message to distant nodes. By incorporating active RFID technology, RMBP optimizes message dissemination, reducing delays, and ensuring reliable communication in VANETs.

3) Sharing tags information

The vehicle whose location is selected transmits its location using a beacon through the wireless systems manager device according to the proposed protocol. As a result, the distance between beacons is not fixed and completely rely on the vehicle's speed and acceleration. Considering that V_p indicates the vehicle' speed at the time of connection with tag T_p and that it advances with a constant acceleration of a to the following tag T_q. With velocity V_q, the vehicle reaches the tag T_q, which can be calculated by Eq. (5).

$$V_q - V_p = \int_0^t a dt' = at \rightarrow V_q = V_p + at \quad (5)$$

If T_p and T_q are placed in locations P_1, P_2, the distance between the tags can be computed by Eq. (6).

$$p_2 - p_1 = \int_0^t dt' = \int_0^t (v + at')dt' = v_0 t + \frac{1}{2}at^2 \quad (6)$$

In the network model, the distance between any two adjacent cells is shown by $p(t)$, and according to $p(t)={}^1/_2 at^2+v_0 t$, a vehicle may travel this distance at a given speed and acceleration. The subsequent time (Δt) of beacon transmission is same as the total number of times a vehicle node has entered in a cell at different velocities and accelerations because a vehicle can update its velocity numerous times when approaching between two continuous cells and broadcast a beacon at each upgrade ($\Delta t = \Delta t'_1 + \Delta t'_2 + \cdots + \Delta t'_n$). Eq. (7) is obtained by analyzing the relationship between distance and acceleration as well as the relationship between distance and velocity

$$p(t) = \left(\int_0^{t_1} v_1 dt + \frac{1}{2}\int_0^{t_1} a_1 dt^2\right) + \left(\int_{t_1}^{t_2} v_2 dt + \frac{1}{2}\int_{t_1}^{t_2} a_2 dt^2\right) + \cdots + \left(\int_{t_{n-1}}^{t_n} v_n dt + \frac{1}{2}\int_{t_{n-1}}^{t_n} a_n dt^2\right) \quad (7)$$

By using information from its single hop and multi hop neighbors, each vehicle in the proposed protocol calculates the next beacon's dissemination time and stores it in a table to lower the likelihood of beacon collisions. Therefore, the reach time of vehicles to the following cells may be calculated based on their present position, velocity, and acceleration. Additionally, to address the hidden issue, the RMBP protocol looks at the time it takes for non-neighbor vehicles that are close by single-hop neighbors to the furthest one to disseminate beacons.

C. Relay Node Selection

Choosing the neighbor which is the furthest away as the relay vehicle, in general, decrease the delay of the message broadcast, improving efficiency of the network. The RMBP protocol chooses the vehicle relay by using the data from the beacons that have been received, and if the direction of the message which is received and the node's motion are the same, the sender of the beacon is chosen as the node which is the farthest away.

Each vehicle in the RMBP protocol identifies its furthest neighbor as well as the two other vehicles that are the furthest away from the other vehicles. These three vehicles are then placed in a list known as the far away list of vehicles. As a result, if the vehicle at the far end of the list did not get the emergency message or was unable to advance it, the remaining vehicles in the list did receive the message and discovered that the vehicle relay has not deliver the packet shall begin to function as next vehicle relay. It is important to modify the far away list of vehicles periodically because when the vehicle speed changes, the vehicles which are rear may get closer. As a result, every vehicle determines its distance from the sender when it gets a message from the vehicle in behind. In case the vehicle is far away from the vehicles on the distant vehicles list, it is replaced with the appropriate vehicle, and the sub list is updated. Additionally, because beacons are not widely dispersed, a vehicle shall contact its neighboring vehicle without the vehicle in front necessarily noticing it. Thus, all the vehicles in the proposed protocol saves the information about neighbors of its neighbors who are not now neighbors with them and may predict how long it will take to get range of the first vehicle and broadcast a beacon upon using it. The flowchart of choosing a relay node is shown in Fig. 8.

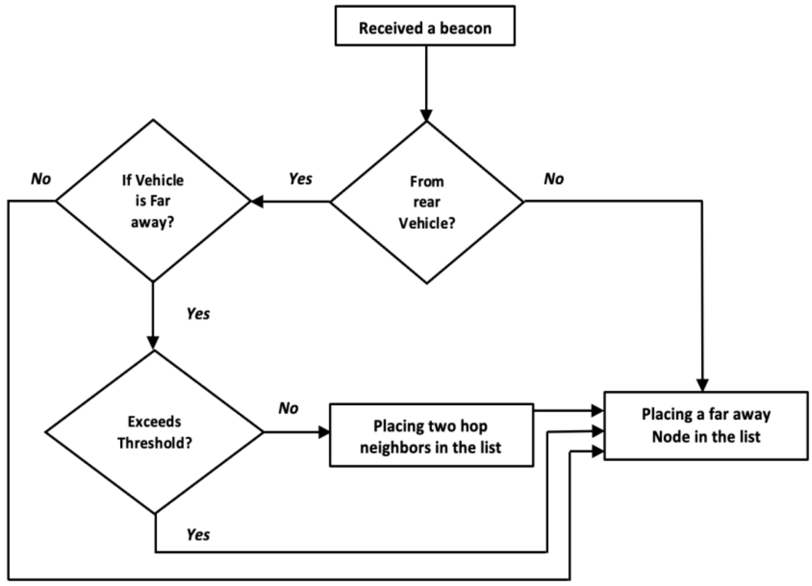


Fig. 8. The flowchart of choosing a relay node.

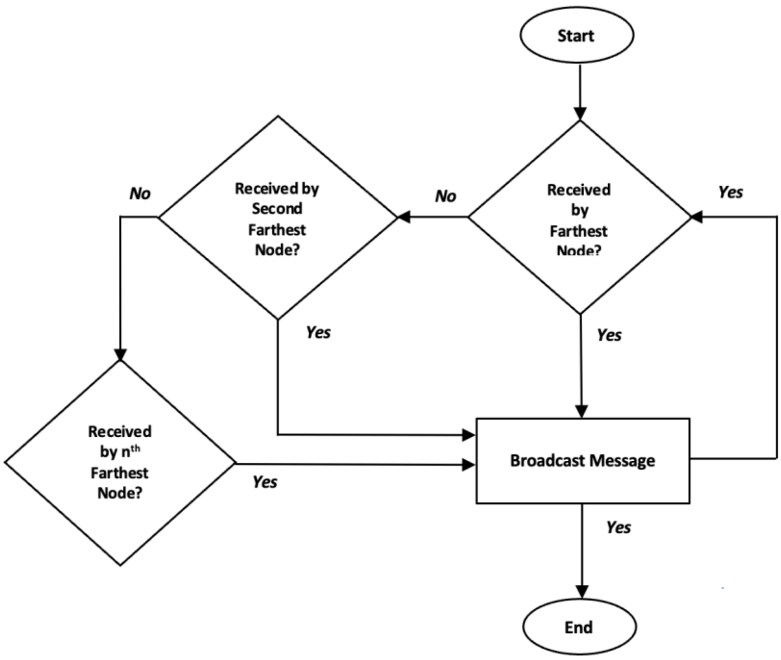


Fig. 9. The flowchart of message broadcasting.

D. Message Broadcasting

The broadcast of messages is done proactive as all vehicles in the RMBP protocol consist a faraway list of vehicles at a given time. In this approach, as soon as a vehicle notices a potentially hazardous situation, it begins sending out a message that includes information about the next hop. If a vehicle gets a message, it takes the specification of the node relay from the message and performs comparison on it to its list of distant vehicles. This vehicle serves as the source node when the receiver vehicle node has been designated as a relay for the message. In order to confirm that the message has been driven by the farthest vehicle, the next farthest vehicle waits to get the message from it. If this vehicle has not got the message once again, it is assumed that the vehicle at the far end did not advance it, in which case this vehicle becomes a forwarder and broadcasts the message. The third far away vehicle is no different. It should be noted that both SH and SSH transmits the packet numerous times based upon the segment as well as its sub segment density, to make sure that message is received by all vehicles in the crucial region. The effectiveness of the protocol may be increased while lowering the danger of running out of nodes by precisely specifying coverage, including termination circumstances, improving transmission schemes, and utilizing routing and relay mechanisms. The proposed protocol's phase-by-phase flowchart for broadcasting emergency messages is depicted in Fig. 9.

IV. Simulation Environment and Results

This section analyses the simulation readings of the RMBP protocol in order to demonstrate that it is more effective than the RSBF-RF [11] and 3P3B-DTN [21] protocols.

A. Environment

The Network Simulator version 3.38 is used, and it runs on a computer with a Windows 11 operating system with an AMD Ryzen 5 Hexa Core CPU clocked at 2.3 GHz, 16 GB of RAM, and other necessary hardware. Table I contains the description of the simulation parameters. The Poisson distribution defines the likelihood of finding k vehicles on the lv length road in the simulated model, which takes into account a three-lane highway with just one direction of travel for vehicles.

TABLE I. Simulation Parameters

Parameters	Values
Standards	IEEE 802.11p
MAC layer	Non-Quality of Service Wave
Bit rate	10 Mbps
Message Size	512 Bytes
Bandwidth	20 MHz
Channel Structure	Yans Wifi
Propagation model (loss)	Propagation coverage
Propagation model (gain)	Fixed rate
Active RFID tag coverage	1 m
Area of Simulation	13.5 m × 2000 m

In the simulation, many cases have been developed with an adjustment in the number, speed, and vehicles acceleration to undertake an extensive examination. The network-based environment is splited into critical as well as non-critical sections in the simulated model so that in the event of an emergency in the critical section, the control centre should be informed quickly.

To verify the reliability of the evaluations, each scenario is run 10 times, with the average being given as the outcome.

B. Results and Discussions

The comparisons made after choosing evaluation parameters which is based on the Information Technology Services (ITS) policy are described as follows.

1) Delay

An important factor in assessing message broadcasting systems is delay. The minimal number of broadcasting hops is often given by the formula $k = l_c/r$, where l_c and r stand for the critical section length and radius of the vehicles. In contrast, in a linked network, the highest number of transmitting hops is $k = 2k$ if there is one rear node and two hop neighbor for the vehicle. Let $t_{acp} = 3\times_{topt}$ be the allowable delay under the situations of the proposed protocol. Let t_{opt} be the optimum latency for k broadcasting hops. It has been noted in a variety of cases, especially in the scenario of worst case, both the count of steps in broadcasting and the delay are less than what is considered acceptable since they are twice as long as the optimal state $(2\times_{topt})$.

The obtained results of RMBP and its comparative protocols in terms of delay (ms) is shown in Table II.

TABLE II. Delay Performance in Various Scenarios

Scenario	RMBP	RSBP-RF	3P3B-DTN
1	0.9	1.8	3.2
2	1.5	2	4
3	1.4	1.6	4
4	1.3	2.2	4.5
5	1.8	2.1	3.1
6	1.6	2.1	2.8
7	1.7	2	4
8	1.4	1.8	3
9	1.5	2	2.8
10	1.5	1.8	2.9
Average	**1.46 ms**	**1.94 ms**	**3.43 ms**

The delay performance of the RMBP protocol and its comparative protocols during message broadcasting is shown in Fig. 10.

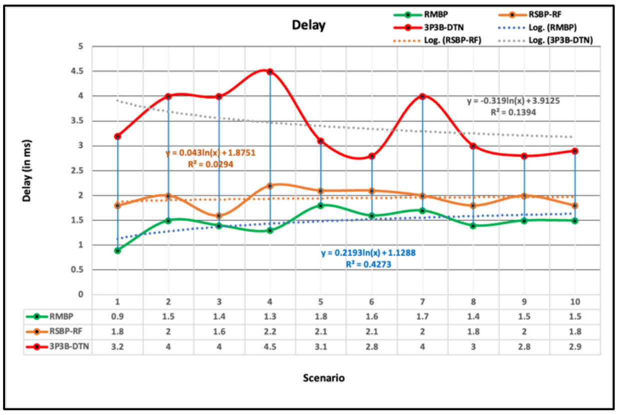


Fig. 10. Delay performance of RMBP and comparative protocols.

2) Packet delivery ratio

The count of packets received by vehicles to the total count of broadcast packets is known as the PDR. According to Friis equation shown in Eq. (8), signal received (P_R) is depends on the signal transmitted (P_T), gain transmitted(Q_T), gain received(Q_R), wavelength signal (λ), and the transmitter-receiver distance (d).

$$P_R = \frac{P_T Q_T Q_R \lambda^2}{(8\pi)^2 d^2} \; (dB_m) \qquad (8)$$

The free-space model is employed in the simulated model, and the values of Q_T and Q_R are taken as 1. Hence, Eq. (8) can be organized as Eq. (9).

$$P_R = P_T \, X \left(\frac{\lambda}{8\pi d}\right)^2 (dB_m) \qquad (9)$$

According to Eq. (8), the signal quality that was received is influenced by the wavelength, and this, in turn, impacts the collision rate of packets, Additionally, because there is no competition, the CW size is zero, hence the chance that a message is sent as P=$(1-P_0)$, where P_0 is the likelihood that the data packet will not be prepared for communication at the MAC. Hence, the simultaneous change in velocity of numerous nearby vehicles might lead to a collision between the beacons.

Eq. (10), which computes the delivery ratio of all connections averaged over the critical zone, determines the average packet delivery ratio.

$$PDR = \frac{\sum_{i=1}^{N-1} r_i}{N-1} \qquad (10)$$

where, PDR is the packet delivery ratio, ri and N denotes PDR of i^{th} link and count of vehicles. A vehicle may have connectivity with other N–1 vehicles in the worst case in a possible dense network. The RMBP protocol's message delivery ratio is greater than that of its rival protocols and the delivery ratios of the RSBF-RF and 3P3B-DTN protocols have been trending lower as vehicle density has increased in various circumstances.

The obtained results of RMBP and its comparative protocols in terms of PDR (ms) is shown in Table III.

TABLE III. PDR PERFORMANCE IN VARIOUS SCENARIOS

Scenario	RMBP	RSBP-RF	3P3B-DTN
1	0	0	0
2	1.6	1	0.8
3	1.7	1.1	0.8
4	1.8	1.8	1.2
5	1.6	1.4	1.5
6	1.9	1.6	2.1
7	2.1	1.2	1.9
8	2.3	1.8	1.2
9	2.4	2.1	1.1
10	2.4	1.9	0.9
Average	**1.78 ms**	**1.39 ms**	**1.15 ms**

The packet delivery ratio of the RMBP and comparison protocols in different contexts is shown in Fig. 11.

3) Throughput

The two most important considerations for assessing the throughput of message broadcasting protocols are generally time and message complexity. The total amount of time needed for placement of tag (AT_p), information reading of tag (AT_r), sharing of tag information (AT_s), selection of relay node (AT_{rn}), and broadcasting of message (AT_b) is the time complexity, which is referred to as the transmission delay. The RMBP protocol embeds active tags as infrastructure into the road, thus the message complexity and time requirements are not impacted by the tag placement process. The reading and exchange of tag information is handled by a network system; therefore, the quantity of vehicles doesn't affect this delay, and their complexity is $AT_r = AT_s = O(1)$. Additionally, each vehicle in each section individually chooses its relay node. In this scenario, if lv is the count of vehicles in each segment (ln) and the neighbors' geographic positions are kept in a structure of tree, the time complexity is equivalent to $AT_{rn} = O(\log_2 l) = O(log_2 n)$, where v is the total count of vehicles.

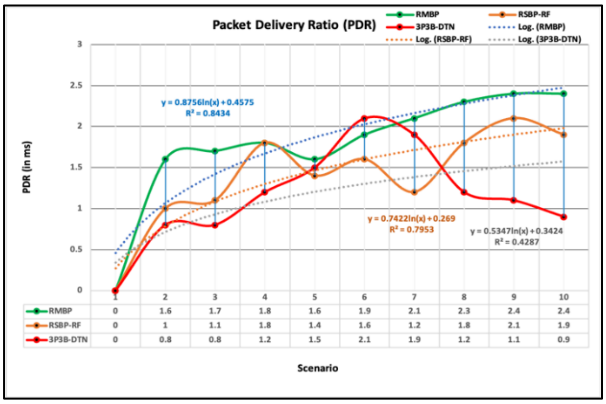


Fig. 11. PDR of RMBP and comparative protocols.

The obtained results of RMBP and its comparative protocols in terms of throughput (bps) is shown in Table IV.

TABLE IV. THROUGHPUT PERFORMANCE IN VARIOUS SCENARIOS

Scenario	RMBP	RSBP-RF	3P3B-DTN
1	55	35	24
2	56	35	22
3	55	42	24
4	58	45	30
5	60	50	30
6	64	53	32
7	70	56	35
8	72	55	42
9	75	64	46
10	78	68	55
Average	**64.3 bps**	**50.3 bps**	**34 bps**

The throughput performance of the RMBP and comparison protocols in different contexts is shown in Fig. 12.

As shown in the Fig. 10, the RMBP protocol exhibits a significantly less delay in comparison with its counterpart protocols which is represented as Low in the Table V.

The performance of packet delivery ratio of RMBP as shown in Fig. 11 is much better in comparison with its counterpart protocols and hence it is represented as High in Table V.

As shown in the Fig. 12, the RMBP protocol achieves a high throughput in comparison with its counterpart protocols which is represented as High in the Table V.

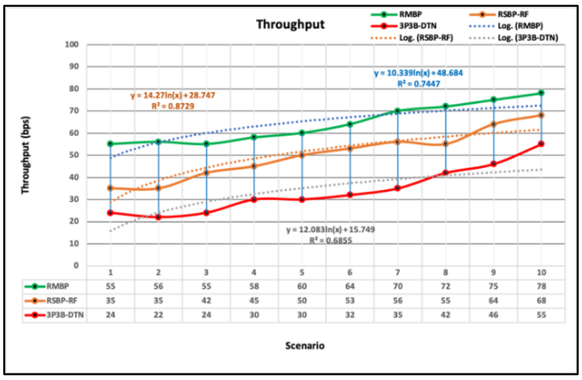


Fig. 12. Throughput performance of RMBP and comparative protocols.

TABLE V. COMPARISON AND SYNTHESIS OF RMBP WITH ITS COUNTERPART PROTOCOLS

Routing Scheme	Delay	Packet Delivery Ratio (PDR)	Throughput
RMBP	1.46 ms Low	1.78 ms High	64.3 bps High
RSBP-RF	1.94 ms Medium	1.39 ms Medium	50.3 bps Medium
3P3B-DTN	3.43 ms High	1.15 ms Low	34 bps Medium

Hence, it can be observed from the above comparison that the proposed RMBP protocol outperforms both the RSBP-RF and 3P3B-DTN protocols in terms of delay, PDR and throughput.

V. CONCLUSION

In this paper, a message broadcasting protocol called RMBP has been designed as a new technology to enhance the broadcasting capabilities of vehicular ad hoc networks. This protocol uses inbuilt active RFID tags to track the location of moving vehicles, readers located in the vehicle control unit to read the tags. Moreover, the route is divided into sections and subsections through ARFID tags to dismiss the issue of broadcast storms. The number of transmitted beacons and their rate of collision have significantly decreased because the beacons are distributed at the instant the vehicle crosses the tags and with a rapid deviation in velocity, and all the vehicles estimate the broadcasting time of the next beacon by using status information. Additionally, the RMBP chooses a distant vehicle to act as the forwarder for all the vehicles to enhance the reliability and dependability of broadcast messages. It also makes use of two different types of radio equipment to reduce interference and minimize competition in the distribution of beacons and broadcast messages. In terms of message delay, packet delivery ratio, and throughput, the simulation results have shown that the RMBP protocol performs better than the RSBP-RF and 3P3B-DTN protocols in a variety of situations. The RMBP protocol has a modest overhead, as shown by an analysis of the time complexity. The actual deployment of active RFID tags needs time and effort in real world scenario. However, future studies can address the trade-off between cost and efficiency as well as between redundancy level and predicted failure tolerance.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

H. Ateeq Ahmed studied the literature, designed the research methodology, analyzed the results, and compiled the manuscript under the supervision of Dhanaraj Cheelu, edited the paper and confirmed the results. Both the authors reviewed and analyzed the results and approved the final version of this manuscript.

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