Journal of Autonomous Intelligence (2023) Volume 6 Issue 2
doi: 10.32629/jai.v6i2.618

ORIGINAL RESEARCH ARTICLE

Future transportation computing model with trifold algorithm for real-time multipath networks

Bharanidharan Chandrakasan[1,*], Malathi Subramanian[1], Hariprasath Manoharan[2], Shitharth Selvarajan[3], Rajanikanth Aluvalu[4]

[1] *Department of Artificial Intelligence and Data Science, Panimalar Engineering College, Chennai 600123, India*

[2] *Department of Electronics and Communication Engineering, Panimalar Engineering College, Chennai 600123, India*

[3] *Department of Computer Science & Engineering, Kebri Dehar University, Kebri Dehar 3060, Ethiopia*

[4] *Department of IT, Chaitanya Bharathi Institute of Technology, Hyderabad 500001, India*

*** Corresponding author:** Bharanidharan Chandrakasan, bharani88.c@gmail.com

ABSTRACT

Purpose: In the past ten years, research on Intelligent Transportation Systems (ITS) has advanced tremendously in everyday situations to deliver improved performance for transport networks. To prevent problems with vehicular traffic, it is essential that alarm messages be sent on time. The truth is that an ITS system in and of itself could be a feature of a vehicular ad hoc network (VANET), which is a wireless network extension. As a result, a previously investigated path between two nodes might be destroyed over a short period of time. **Design:** The Time delay-based Multipath Routing (TMR) protocol is presented in this research which efficiently determines a route that is optimal for delivering packets to the target vehicle with the least amount of time delay. Using the TMR method, data flow is reduced, especially for daily communication. As a result, there are few packet retransmissions. **Findings:** To demonstrate how effective the suggested protocol is, several different protocols, including AOMDV, FF-AOMDV, EGSR, QMR, and ISR, have been used to evaluate the TMR. Simulation outcomes show how well our suggested approach performs when compared to alternative methods. **Originality:** Our method would accomplish two objectives as a consequence. First, it would increase the speed of data transmission, quickly transfer data packets to the target vehicle, especially warning messages, and prevent vehicular issues like automobile accidents. Second, to relieve network stress and minimize network congestion and data collisions.

Keywords: routing protocols; intelligent transportation system (ITS); vehicle-to-vehicle (V2V) protocol; time delay-based multipath routing (TMR) protocol

ARTICLE INFO

Received: 4 May, 2023
Accepted: 1 June, 2023
Available online: 22 August, 2023

1. Introduction

ITSs on vehicular ad hoc networks (VANETs) have emerged in recent years as a crucial and well-liked research area in the transport sector[1]. ITS is a sophisticated application that speeds up node movement in a network to deliver information for a variety of purposes, including signals, congested traffic, and danger zones on the road, ITS vehicles interact and communicate with one another. Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication are the two major forms of communication used to build vehicular ad hoc networks[2]. The deployed vehicles with On-Board Units (OBU) in the system make use of V2V communication. The interaction between vehicles and roadside units is made possible via V2I communication (RSU)[3]. There are two different sorts of messages used in V2V and V2I communications: regular communications and emergency notifications. The RSU receives the routine communications, which also contain information from the Global Positioning System (GPS), along with any other vehicles in its range. Other responders must be informed of the collision details in the emergency alerts so they can take swift action. Because of this, the appropriate location receives the accident notice for the vehicle before regular communication. To optimize packet delivery while tolerating data loss as little as possible, VANET connects with fast moving nodes and alongside RSU[4,5]. Since time is a crucial factor in preventing car collisions, especially on highways and roadways, the data from an accident must be communicated as soon as possible to all nodes in the network. In comparison to a single route routing system, a multipath routing protocol is superior at managing huge volumes of data, balancing the data flow, and controlling time.

Similar to single route approaches like the Ad-hoc On-demand Distance Vector (AODV) protocol, multipath protocols offer backup routes in case of connection failure without requiring a route discovery phase. Subsets of mobile ad hoc networks are VANETs (MANETs), according to Manoharan[6]. It must be possible for routing in VANETs to increase traffic efficiency. In the case of a channel disconnect, Ad hoc On-Demand Multipath Distance Vector (AOMDV) offers alternate paths based on the fewest possible hops. The nodes' state in terms of having traffic issues is not taken into account, though. The centralized ITS that we suggest in this research would allow cars to communicate information to the RSU, which would then transmit it to other vehicles. For infrastructure-to-vehicle (I2V) data connections in the event of emergency notifications, RSU will employ our TMR protocol. The time needed for data transmission is shortened since these signals are sent to all moving cars to help prevent serious accidents without going through the route-finding process first. The probability of traffic issues involving vehicles would surely be reduced by this. This requires that a specific dynamic threshold be achieved in order to find a route. RSU must wait for a back off period before moving further with the discovery stage, which increases proximity between intermediate cars while reducing traffic.

1.1. Literature review

In the survey of Sivamaran et al.[7] and Yu et al.[8], A new protocol called LBMMRE-AOMDV stands for load balancing maximal minimum nodal residual energy on-demand multipath distance vector routing that the authors suggest as an improved version of the AOMDV protocol. There are two phases to the protocol. When one or more paths fail, the first builds fragmented link paths and maintains them. The data load is distributed evenly among the created link-disjoint pathways in the second phase. The protocol assesses the created paths during these phases to establish the maximum nodal residual energy and the actual number of packets that can be transmitted over that path without exhausting the nodes' energy. When the number of dead nodes is taken into consideration, the outcomes demonstrate improved performance in terms of packet delivery ratio and energy use[9]. It does, however, have a constant end-to-end latency. The authors suggest using this strategy in applications like banking a result as well as online buying instead of general uses.

An Enhanced Hybrid Routing Protocol in Vehicular Ad-hoc Networks (TIHOO) is a hybrid protocol developed by Zhang et al.[10] that uses fuzzy logic and the AODV algorithm to limit the route finding process. This algorithm engages actively and it is effective. Manoharan et al.[11] on the other hand, concentrated on lowering energy usage utilizing the FF-AOMDV protocol. The optimum multipath routing is chosen by FF-AOMDV using the fitness function. It is demonstrated that the FF-AOMDV algorithm outperforms AOMDV and AOMR-LM in terms of energy usage, packet delivery ratio, throughput, end-to-end delay, and routing overhead ratio (Ad-hoc On-Demand Multipath Routing). There is an improvement in end-to-end latency since the fitness function takes so long to process. The multi-objective auto-regressive whale optimization (ARWO) approach and a traffic-aware routing protocol for VANET were both offered by Meneguette[12]. By taking into consideration many goals including end-to-end delay, ARWO chooses the optimum way from among several paths. On the other hand, if there is a huge amount of congestion and traffic on the routes, it faces network overload since every vehicle tries to identify the finest path to go to the destination. Fault-Tolerant Disjoint

Multipath Distance Vector Routing Algorithm (FDAOMDV) is first described in the survey of Zantalis et al.[13]. By using the extra energy of the intermediate nodes, this technique determines the shortest way, but it compromises the number of nodes in the chosen path, increasing the transmission time.

Ouallane et al.[14] improved the reliability and latency of VANETs by introducing a revolutionary V2V-enabled resource allocation system based on cellular vehicle-to-everything (C-V2X) technology. A failure detection method based on VANET architecture is proposed by Qureshi et al.[15]. They discussed the failure detector can change to adapt to shifting network conditions and provide various applications on VANETs with the Quality of Service (QoS) they require. Failures in the communication links between the vehicles may be avoided. The main disadvantage of the strategy is the additional routing brought by the additional detection messages. Yuvaraj and Sangeetha[16] presented the QMR routing protocol, a multi-objective optimization technique based on Q-learning. The inventor of this protocol makes an effort to maximize network efficiency and latency by utilizing both proactive and reactive routing strategies. GPS is installed in each network node. Each node has the ability to choose whether to send the data packets based on the observed distance and residual energy. The routing overhead for this protocol is rather heavy and requires the exchange of positioning and basic status information between neighboring nodes to support vehicular applications. In the survey of Elmesmary and Said[17] and Sepulcre et al.[18] discussed the fastest route for ambulance vehicles was chosen using a strategy that suggested setting a service-level agreement (SLA) organized with the energy collaboration for path development. Energy is not the primary problem with VANETs because the battery provides a reliable supply of power. Additionally, the temporal complexity is rather high, making it unsuitable for essential applications like an ambulance. The primary flaw in the topological method is that it fails to take mobility into account when designing routing protocols. With regard to cars and edges, the connectivity between nearby nodes topological routing techniques treats the network as a graph of nodes. The built-in graph is regularly vulnerable to modification since VANETs has rapid mobility.

The primary flaw in the topological method is that it fails to take mobility into account when designing routing protocols. With regard to cars and edges, the connectivity between nearby nodes topological routing techniques treats the network as a graph of nodes. The built-in graph is regularly vulnerable to modification since VANETs has rapid mobility. The graph must be rebuilt when a connection fails, which comes with a substantial end-to-end delay. In the survey of Lee et al.[19], to choose the following hop, the authors suggested using the Multi-metric Geographic Routing (M-GEDIR) method. The probability that the area is safe or risky, the dynamic forwarding region is used to select the next node vehicle. Since the roadside unit is not considered, it is a V2V communication. This is an impractical strategy since it takes a while to figure out the best course of action. In the survey of Barykin et al.[20], the traffic light-aware routing system with the shortest path and the intersection-based routing approach were combined to create the mechanism. The protocol’s creators called it the Reliable Path Selection and Packet Forwarding (RPSPF). The protocol’s creators called it the Reliable Path Selection and Packet Forwarding (RPSPF). An intersection’s traffic patterns and traffic light signals and data packets are used to transfer. The protocol may have a high throughput and packet delivery ratio. However, it has connection problems. For instance, if one node departed the network, end-to-end communication between the vehicles would be destroyed. In an intersection’s traffic patterns and traffic light signals, data packets are transferred. The protocol may have a high throughput and packet delivery ratio. However, it has connection problems. For instance, if one node departed the network, end-to-end communication between the vehicles would be destroyed.

1.2. Research gap and motivation

The protocols base the choice of the path on a number of factors, including hop count, etc. The proactive and reactive routing protocols currently used by VANETs include ad hoc on demand distance vector (AODV), destination-sequenced distance vector (DSDV), dynamic source routing (DSR), and optimum link state routing

(OLSR)[11]. The protocols base the choice of the path on a number of factors, including hop count, etc. The main issue with data routing between cars is connection failure based on node mobility, especially at high speeds[21,22]. To decrease the traffic flow on the network and thus improve its network performance, it is needed to suggest a protocol that takes into consideration and this mobility issue as well as how to avoid network congestion[23–25].

In this article, we introduce the TMR multipath routing protocol, which operates in a VANET environment. Instead of using the smallest number of steps, TMR chooses the shortest route based on the RTT measurement. When one path fails, data messages are transferred through the next-least-slowest path. To assess a potential route, TMR establishes a threshold value that limits a measured instant RTT. To avoid flooding the network with data packets when RTT or node mobility are both high, this threshold is the average RTT that is set. Our protocol is built to distinguish between an emergency and a regular message. While routine messages are moved to the back of the queue, emergency messages are forwarded to the receiver immediately. To avoid flooding the network with data packets when RTT or node mobility are both high, this threshold is the average RTT that is set. Our protocol is built to distinguish between an emergency and a regular message. While routine messages are moved to the back of the queue, emergency messages are forwarded to the receiver immediately. While routine messages are placed into the order using the FIFO queuing algorithm and sent over the TMR protocol, emergency communications are sent to the destination immediately.

While routine messages are placed into the order using the FIFO queuing algorithm and sent over the TMR protocol, emergency communications are sent to the destination immediately.

1.3. Major contributions

Therefore, the following contributions can be made using our suggested routing TMR algorithm:

- Give ITS emergency communications a higher priority than regular packets. Deliver emergency data and warning packets on time within the VANET system to avoid vehicle traffic congestion.
- Choose the quickest route with the least amount of delay to accelerate the data transfer.
- TMR selects the optimal route using the least RTT, allowing it to adjust to topological changes.
- In order to add a route to the array of efficient routes, our protocol uses a threshold value that must be greater than the RTT value.
- Minimize the number of data packets that must be retransmitted in order to minimize data traffic load and hence improve network performance.

2. Methodology

2.1. End-to-end (E2E) delay

End-to-end: when a packet is delayed, it means that it took longer than expected to go from its source to its destination through the network. In most cases, it is expressed in seconds.

$$E2E(in\ Seconds) = \frac{\sum_{i=1}^{n}(R_i - S_i)}{n} \tag{1}$$

where, R_i stands for the simulated time when the packet is delivered at the receiving end. S_i, represents the time at which the package is dispatched. n is the total number of packets delivered.

2.2. Packet loss ratio (PLR)

The PLR measures the proportion of packets that didn’t reach their destination out of all the packets transmitted.

$$PLR(in\%) = \frac{\sum P_l}{\sum P_g} \times 100 \tag{2}$$

where, P_g stands for the number of packets produced and P_l is for the number of packet loss.

2.3. Throughput

The throughput, which is measured in Mbps, is the total number of packets that all nodes successfully receive in a given amount of time.

$$G(in\ Mbps) = \frac{\sum B_r \times 8}{T} \times 10^{-6} \tag{3}$$

where, "G" in the following equation denotes the total amount of bytes sent successfully, the network that sent data at that time is indicated by "T".

2.4. Routing overhead (RO)

A percent (%) is used to express how many routing packets are needed for network communication.

$$RO(in\%) = \frac{R_p}{R_p + D_p} \times 100 \tag{4}$$

where, R_p represents the number of routing packets and D_p represents the number of delivered data packets.

2.5. Energy consumption (EC)

All nodes, regardless of their condition, utilize the same amount of energy during the simulation.

$$EC(in\ Joules) = \sum_{i=1}^{n} (I_i - E_i) \tag{5}$$

where, n is the number of nodes, I_i is the initial energy of node i, and E_i is the energy node i has left at the end of the simulation.

3. Trifold optimization algorithm

The main goal of TMR, a multipath routing method based on RTT, is to decrease end-to-end time delays. The TMR algorithm uses the principles of message processing, routing path selection, and RTT. The main goal of TMR, a multipath routing method based on RTT, is to decrease end-to-end time delays. The TMR algorithm, uses the principles of message processing, routing path selection, and RTT, as shown in **Figures 1–3**.

The primary elements of the message behavior in the VANET depicted in **Figure 1** are described in more detail below. **Figure 2** shows how data is transferred at the on-board unit (OBU).

Despite simply providing one way, it is based on a time delay. Similar to the AODV protocol, this protocol has to resume the route detection method in the event of a connection failure to locate a different path. The OBU would transmit a message to RSU, which would then broadcast (in an emergency) or unicast (in a regular message to a particular vehicle)[10] the message to some other vehicle OBU. The frame format for unicast transmission with regular messages is shown in **Figure 3**.

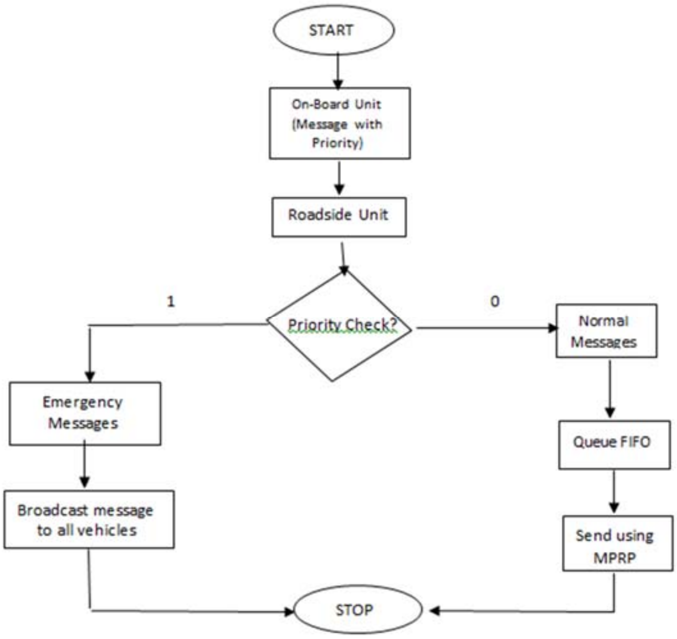

Figure 1. Process flow diagram for message handling.

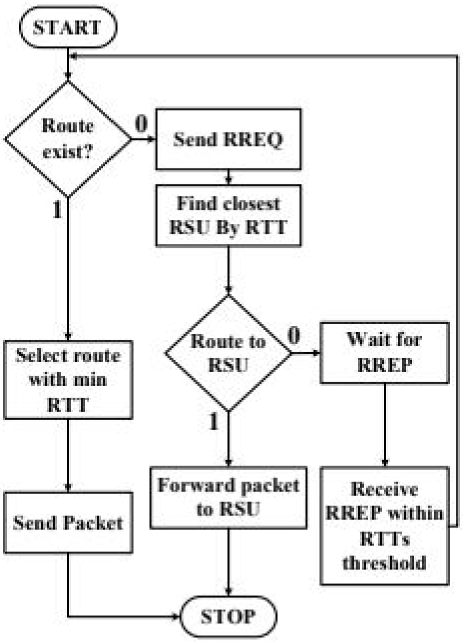

Figure 2. OBU packet forwarding flowchart.

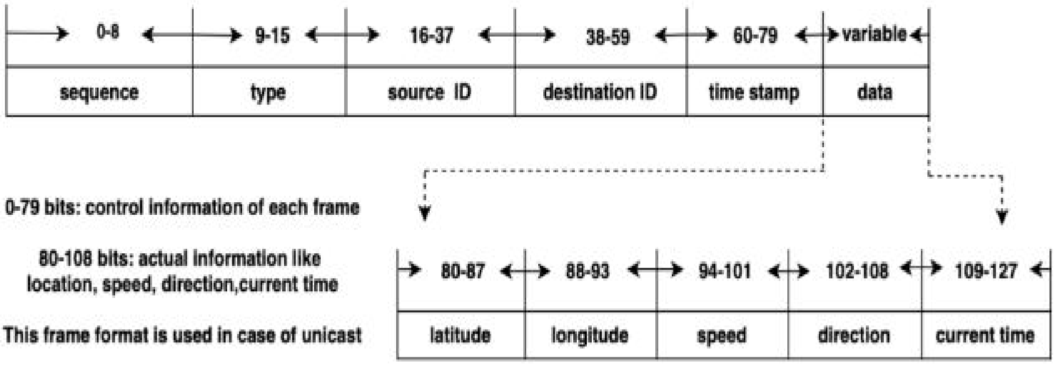

Figure 3. Normal packet format.

Algorithm 1 Message handling

```
First method: at onboard unit
    Send OBU communication
    Check for the condition if type is equals to emergency
        Set the value for weight as 1
    Otherwise assign the normal value to ~type
        Set the value for weight as 0
    If condition stops here
Method stops here
Second method: At roadside unit
    Check OBU communication
    Check if load equals 1 then
        Send the broadcast message
    Otherwise assign the value as 0 to ~ weight
        Push notification will be sent to the queue in FIFO basis
        Send data message using TMR in Algorithm 3 (TMR routing protocol)
    If condition stops here
End method stops here
```

Algorithm 2 Routing path establishment

```
First method AT RSU: getting a communication from a vehicle that has to be passed on to some other vehicle
    Checking the routing table
    Set path to destination equal to null
    Send request to produce RREQ (VID)
    If not, broadcast the RREQ (VID) request to all nodes (vehicles)
    Else
        Proceed Algorithm 3 (TMR routing protocol)
    If condition stops here
End method stops here
Second method AT OBU AND RSU: Receiving RREQ message
    If RREQ (VID) request submitted
        Set (new VID equal to old VID)
        Delete the request RREQ
    Else
        Adding new VID to CRL
    If condition stops here
End method stops here
Third method AT OBU: Receiving RREQ message
    If (there is a route to the target) then
        Send request RREP to the RSU
        RTT is evaluated at the RSU
    Else
        Transmission request RREQ (VID) to other adjacent nodes
    If condition stops here
End method stops here
```

Algorithm 3 TMR routing protocol

```
at RSU
While (RREP = true) ~ RREPs received from Algorithm 2
    Method 1: Calculating average $RTT_{ij}$
        ~$RTT_{ij}$ received from Algorithm 2
        $RTT_{ia} = \frac{\sum_{j=1}^{n} RTT_{ij}}{n}$
    End method stops here
    Method 2: Path selection
        If ($RTT_{ij} > RTT_{ia}$) then
            Delete $RTT_{ij}$ route
        Else
            Add $RTT_{ij}$ into an array A [ ]
        Sort array A [ ] in an ascending order
        Update the routing table
```

Algorithm 3 (*Continued*)

```
If condition stops here
Send a message using a route with the minimum $RTT$ in A [ ]
If (timeout) then
    Send a message using a route with the next minimum $RTT$ in A [ ]
If condition stops here
End method stops here
```

4. Results and discussions

NS-3 (version 3.30.1) was employed with Ubuntu 20.04.2 to evaluate TMR's performance. To obtain simulation results, use LTS as your operating system. Although throughput, end-to-end latency, packet delivery, packet loss rates, are examples of quantitative performance measures. In the simulations, we consider a number of network configurations with vehicle nodes that are placed at random.

Table 1. Parametric standards.

Parameter types	Parameter values
Network simulator ns–3.30.1	Network simulator ns–3.30.1
Traffic simulator	SUMO 1.7.0
Wireless protocols	IEEE 802.11
Standard physical layer and MAC layer	OFDM rate (7 Mbps, 10 Mbps, 14 Mbps, 20 Mbps, 26 Mbps, 30 Mbps, 50 Mbps, 56 Mbps) 20 MHz
Protocol present	AOMDV, TSR, FF-AOMDV, EGSR, QMR, ISR and TMR
No. of rounds	8
Simulated time	1 Min
No of nodes	40, 50, 60, 70, 80, 90, 100, 110, 120, 130
Mobility speed	Each 5 ms
No. of links	5, 8, 10, 11, 14, 17, 20, 23, 26, 29
Payload data	256, 512, 768, 1024, 2048, 3072 bytes per packet
Transmitted speed	1 Mbps
Power transmitted	8 db
Initial energy source	150 Joules
Energy transmitted	0.2 watt
Energy received	0.1 watt

When assessing the performance of the network, consider varying network loads, concurrent connections, different packet sizes, and environmental factors including mobility speed and node count. The generated parameters are shown in **Table 1**. Except for particular instructions, all tests are run using the **Table 1** parameter assumptions. The outcomes show that our methodology remains effective when the number of nodes rises. When assessing the performance of the network, consider varying network loads, concurrent connections, different packet sizes, and environmental factors including mobility speed and node count. The outcomes show that our methodology remains effective when the number of nodes rises. Since the TMR network architecture included stationary RSU nodes, an effort was made to create an equal simulation environment for each protocol.

Since the TMR network architecture included stationary RSU nodes, an effort was made to create an equal simulation environment for each protocol. In all simulations, the same number of stationary nodes were present in the network at the same position due to the same parameter.

4.1. Case study 1

In the case study shown in **Figure 4**, we took into account a scenario where data transmission takes place between OBUs and the RSU nearby on one road segment. In this case, the study's goal is to assess how well each technique performs on a certain road stretch. The TMR protocol's simulation results against those of AOMDV, TSR, FF-AOMDV, QMR, and EGSR are shown below.

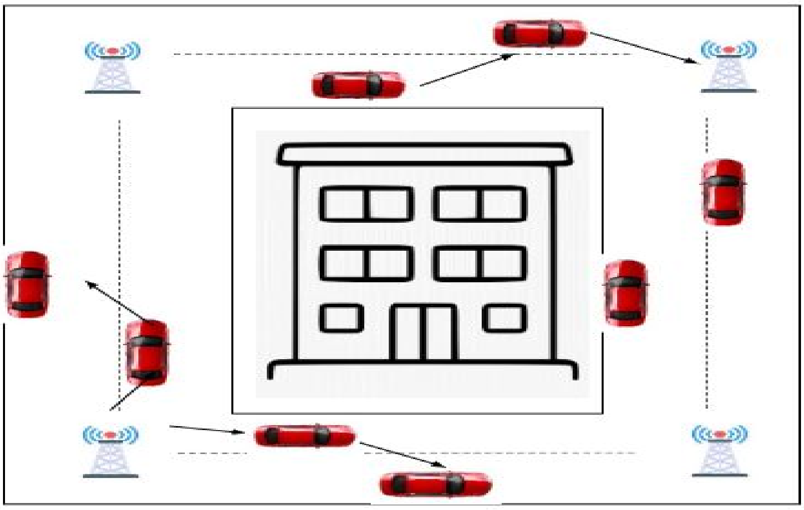

Figure 4. Data transmission on a single road section.

In **Figure 5**, TMR increases in PLR as more data can be effectively sent to the target vehicle, as shown by Equation (2). The best routes for TMR employ the threshold mechanism shown in Algorithm 3, which has an RTT that is less than the accepted standard RTT. This lowers the PLR. The performance of EGSR and QMR protocols is comparable to TMR since they use route selection algorithms that also take time into account. Other protocols do not take this delay into account; therefore, it is possible that data packets arrive slowly and PLR grows. Furthermore, multipath protocols, such as TMR, perform better than TSR, especially in the event of a connection breakdown. Whenever a connection fails, TSR is forced to re-compute the shortest path, which raises the PLR. TSR performs badly compared to the other protocols when used as a single-route protocol. In order to get findings that are more accurate, we remove them from other figures. Similar to how we eliminate AOMDV from other numbers due to its poor performance.

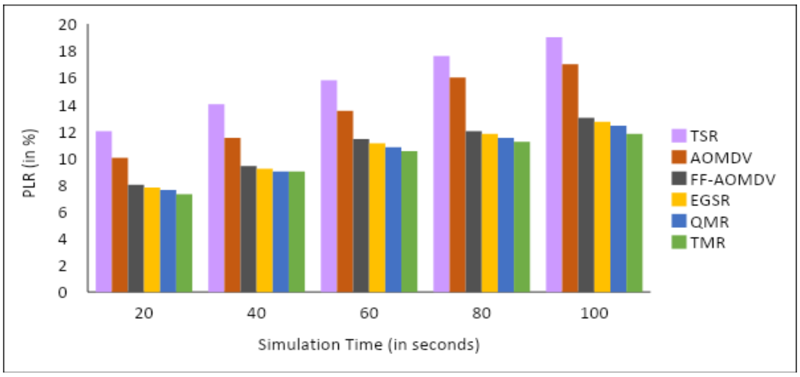

Figure 5. Suggested protocols for PLR using simulation time.

4.2. Case study 2

The break period is the duration for which the vehicle is halted. The simulation findings that follow utilize the distance of the red light at the traffic signal as the stop period. As shown in **Figure 6**, the end-to-end latency gets shorter when there is a longer pause period. This issue occurred because there have been fewer connection failures, which are caused by the topological shift. The amount of time the sender should spend processing ICMP error signals decreases as there are fewer connection failure instances. The simulation findings that follow utilized the distance of the red light at the traffic signal utilized stop period. As shown in **Figure 6**, the end-to-end latency gets shorter when there is a larger pause period. This issue occurred because there have been fewer connection failures, which are caused by the topological shift. The amount of time the sender should spend longer ICMP error signals decreases as there are fewer connection failure instances.

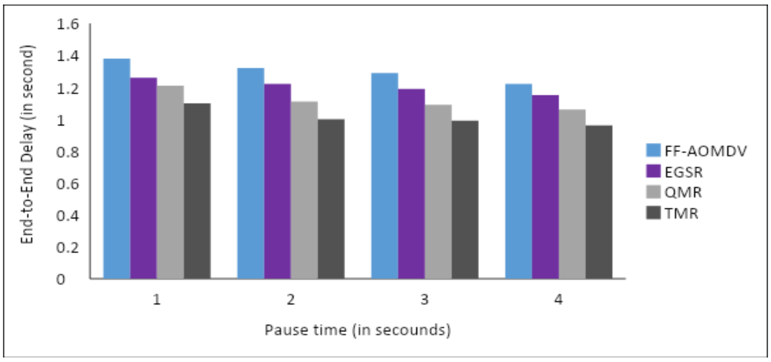

Figure 6. End-to-end delay with stop time comparison.

This issue occurred because there have been fewer connection failures, which are caused by the topological shift. The amount of time the sender should spend processing ICMP error signals decreases as there are fewer connection failure instances. Longer stop times increase performance because QMR prefers to send data packets through its nearest neighbors with mobility speeds that are slower than average. **Figure 7** demonstrates that by extending the pause time. All procedures have decreased energy usage. All protocols would send less data if the pause intervals were extended, which would require less energy. The longer stop times increase performance because QMR prefers to send data packets through its nearest neighbors with mobility speeds that are slower than average. **Figure 7** demonstrates that by extending the pause time. All procedures have decreased energy usage. All protocols would send less data if the pause intervals were extended, which would require less energy.

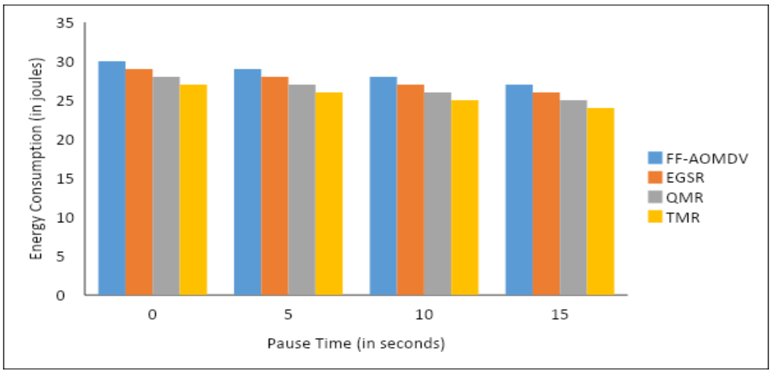

Figure 7. Energy consumption with pause time.

4.3. Case study 3

In this section, to determine the information load size with the greatest number of packets received, several packet sizes are taken into account. The following tests are then performed using the chosen packet size.

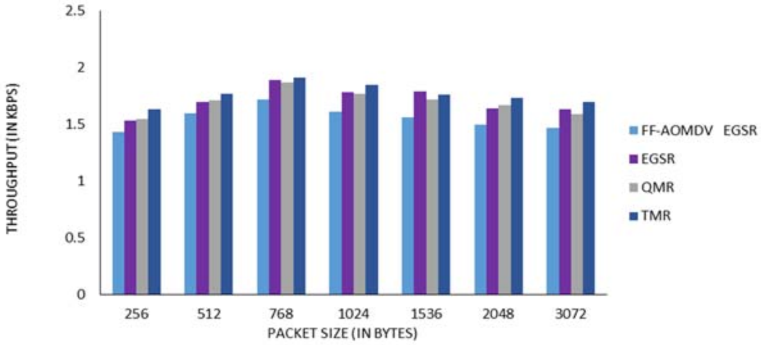

Figure 8. Comparison of TMR proposed protocol with various packet sizes.

In **Figure 8**, throughput has been computed using Equation (3), which demonstrates that it rises with packet size until it exceeds 768 bytes. The network subsequently experiences data congestion, which causes the throughput to decrease. In **Figure 8**, throughput has been computed using Equation (3), which demonstrates that it rises with packet size until it exceeds 768 bytes. The network subsequently experiences data congestion, which causes the throughput to decrease. However, as was already indicated, TMR uses routes with the shortest RTT to have the least impact on data transfers from congestion.

In **Figure 9**, the expansion in data load size is accompanied by an increase in delay, as seen in **Figure 10**. Due to the lowest PLR in this scenario, TMR exhibits the lowest energy use. AOMDV, on the other hand, displays the worst outcome as a result of a growing bottleneck that raises the possibility of data congestion and collision. The waiting time is the key contributor to an increase in end-to-end delays. The appropriate way to reduce end-to-end delay is to prevent data congestion from occurring. The robust end-to-end performance of TMR illustrates the effectiveness of its strategy for identifying data traffic issues in terms of the RTT threshold value.

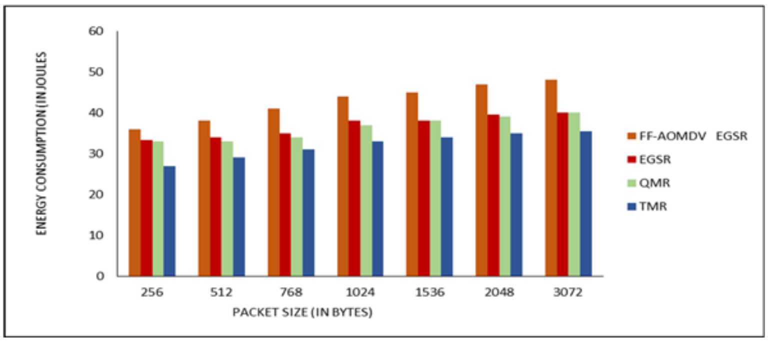

Figure 9. Energy usage and various packet sizes.

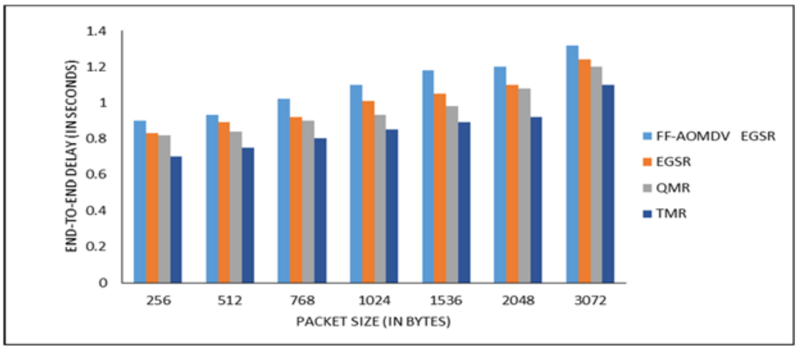

Figure 10. End-to-end latency for various packet sizes.

4.4. Case study 4

In **Figure 11**, we selected 0, 5, 10, and 25 as the proportion of problematic nodes. In the case of multipath methods, the throughput drops as the number of defective nodes rises as a result of data loss during the interval between the routes. For each node failure, the transmission will stop during the route-finding phase. Since minimal RTT uses the fewest nodes and travels the shortest distance, this increases throughput. In **Figure 12**, an effect of the ratio of defective nodes growing is an increase in energy consumption.

In the case of multipath methods, the throughput drops as the number of defective nodes rises as a result of data loss during the interval between the routes. For each node failure, the transmission will stop during the route-finding phase. Since minimal RTT uses the fewest nodes and travels the shortest distance, this increases throughput. The PLR obviously rises with a huge rate of malfunctioning nodes, and this increases the number of data packets sent again. More routing packets are required in this situation for the network to maintain a

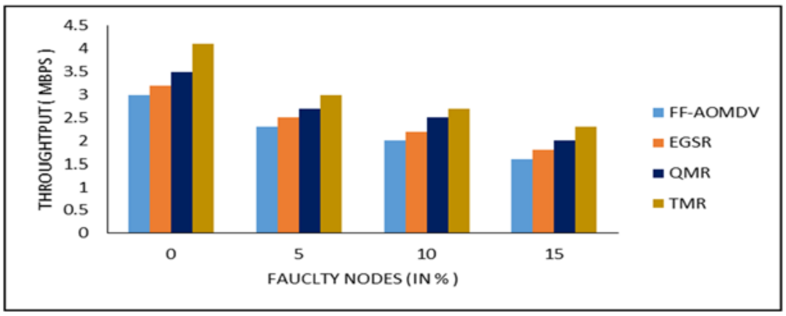

Figure 11. Throughput with defective nodes.

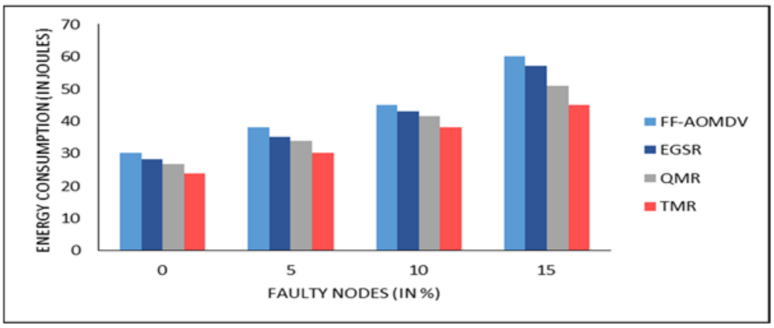

Figure 12. Energy usages with malfunctioning nodes.

connection. Such additional data loads use quite a lot of the node's energy.

Figure 13 illustrates that the throughput is huge in comparison to other protocols. To send more packets to the target node in a given time interval, TMR selects the path with the least RTT. Additionally, as noted before, the path chosen using this strategy will avoid traffic. In comparison to FF-AOMDV, EGSR, and QMR, **Table 2** demonstrates improvements in TMR of 14.93%, 9.13%, and 5.88%, respectively.

As illustrated in **Figure 14**, as the number of nodes choosing the best route from among those available increases, so does the end-to-end latency. Multipath protocols reduce delays because backup pathways are always available. The TMR algorithm may identify and choose the least congested link, resulting in a minimum queuing time and, in comparison to other protocols, a relatively short end-to-end delay. **Table 3** contains the relevant data. Comparing TMR to FF-AOMDV, EGSR, and QMR, the end-to-end delay is reduced by 20%, 13%, and 9.9%, respectively.

As shown in **Figure 15**, it is evident that when nodes increase, fewer packets are delivered. Due to the backed-up traffic, a significant quantity of data loss and deletion will occur. TMR performs better than other protocols since, as was already said, it chooses the path based on its dependability. Additionally, TMR employs the threshold mechanism, which lowers packet loss.

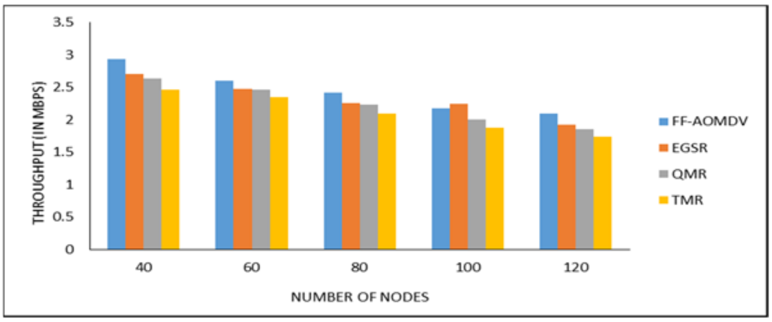

Figure 13. Throughput with number of nodes.

Table 2. Number of nodes versus throughput.

# Node	FF-AOMDV	EGSR	QMR	TMR
40	3.15	3.75	3.75	4.00
50	3.10	3.55	3.60	4.75
60	3.37	3.45	3.50	3.60
70	2.30	3.40	1.45	3.50
80	2.15	1.30	1.30	1.40
90	2.15	1.10	1.25	1.45
100	2.90	1.15	1.15	1.20
110	1.80	22.98	2.00	1.18
120	1.82	2.99	2.01	1.19
130	1.80	2.89	2.90	1.15
Sum	15.70	18.82	20.50	24.80
Gain (%)	15.15	10.14	8.85	4.0

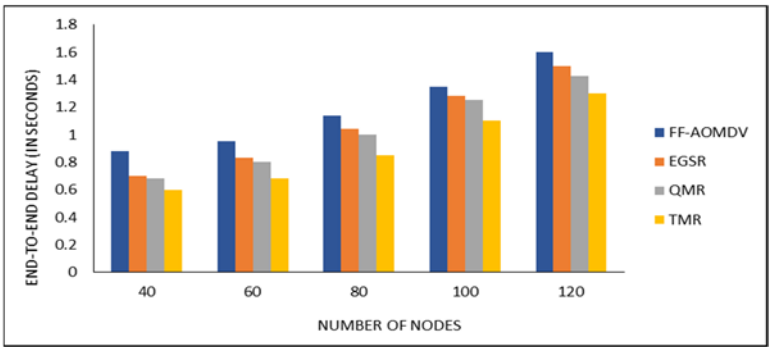

Figure 14. Comparison of end-to-end latency with node count.

Table 3. Number of nodes versus end-to-end latency.

# Node	FF-AOMDV	EGSR	QMR	TMR
40	1.88	1.77	1.68	1.64
50	1.97	1.79	1.75	1.70
60	1.99	1.88	1.85	1.71
70	0.15	1.96	1.91	1.74
80	0.15	0.15	0.20	1.90
90	0.30	0.18	0.10	1.99
100	0.40	0.30	0.30	0.15
110	0.49	0.45	0.35	0.30
120	0.70	0.50	0.50	0.35
130	0.75	0.60	0.54	0.50
Sum	15.32	13.40	09.81	7.75
Gain (%)	22.91	18.60	10.90	08.22

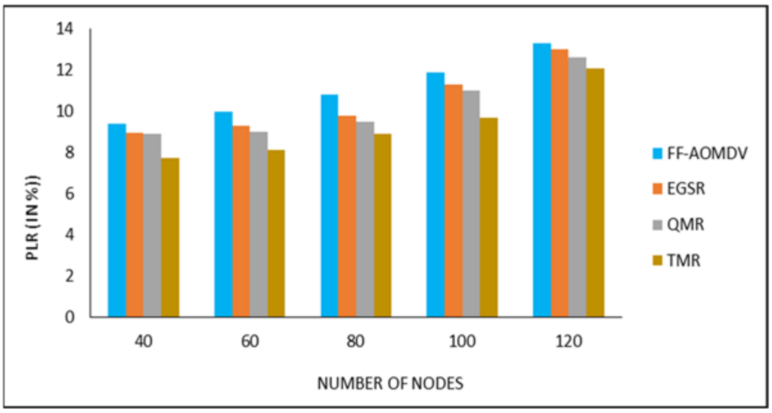

Figure 15. Comparison of PLR with number of nodes.

4.5. Case study 5

Figure 16 gives an example of the circumstances in question. The sender and recipient nodes were chosen at random by the simulator. Compare both the QMR and ISR protocols with the TMR protocol, since the ISR method was created to function well in the given circumstances. **Figure 16** shows how all of the protocol throughput performance decreases during the course of the experiment. The TMR algorithm selects the effective route based on the lowest RTT and avoids links with heavy traffic congestion.

Since the source and destination of OBUs are located in separate road sections, there is no pair of source and destination road segments that are identical. **Figure 16** gives an example of the circumstances in question. The sender and recipient nodes were chosen at random by the simulator. Compare both the QMR and ISR protocols with the TMR protocol, since the ISR method was created to function well in the given circumstances. **Figure 16** shows how all of the protocols' throughput performance decreases during the course of the experiment. The TMR algorithm selects the effective route based on the least RTT and avoids links with heavy traffic congestion, which results in the maximum performance; this performance is very promising. Sender and recipient nodes were chosen at random by the simulator. Compare both the QMR and ISR with the TMR protocol, since the ISR method was created to function well in the given circumstances. The TMR algorithm selects the effective route based on the least RTT and avoids links with heavy traffic congestion, which results in maximum performance.

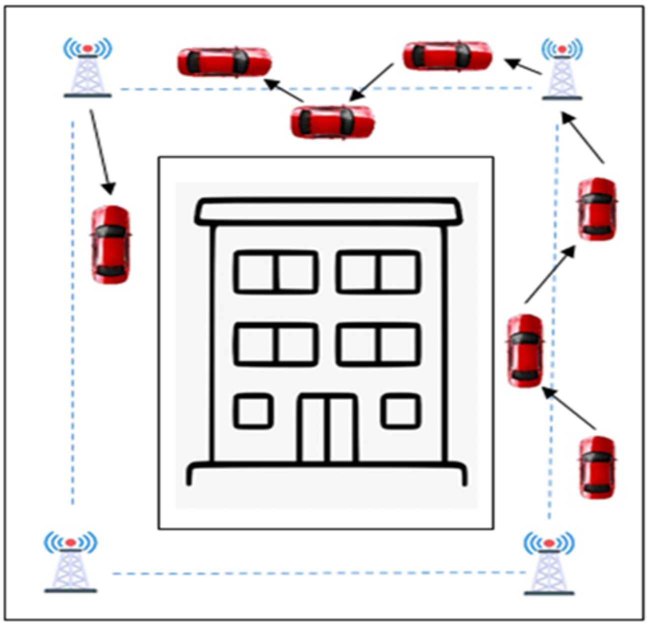

Figure 16. Data transmissions across numerous road segments.

Table 4 shows that TMR increases throughput in comparison to QMR and ISR by 15.4% and 6.4%, respectively. Similar to how TMR PLR in **Figure 17** is the lowest, demonstrating its innovative performance. In Algorithm 3, the threshold value of the TMR mechanisms chooses the routes of RTT that are less than the ordinary RTT value. Extended paths are consequently eliminated, which lowers the likelihood of a connection breakdown. Because of its path-choosing system. The route-finding phase of TMR is started at a slower rate than that of other protocols since TMR has less PLR value.

As the network receives more traffic over time, the end-to-end delay also increases, as seen in **Figure 18**. Since the TMR, has the least delay because of its path-choosing system, the route-finding phase of TMR is started at a slower rate than that of other protocols since TMR has less PLR value. As illustrated in **Figure 18**, this lowers the routing overhead ratio. Because the TMR does not utilize these routing packets, the QMR and

Table 4. Simulation time vs. throughput.

Time	QMR protocol	ISR protocol	TMR protocol
10	3.55	3.60	3.70
20	3.30	3.40	3.53
30	3.15	3.29	3.40
40	3.90	3.10	3.30
50	2.90	2.00	3.15
60	2.80	2.01	1.15
70	2.70	2.99	2.00
80	2.71	2.94	2.98
90	2.72	2.88	2.99
100	2.68	2.80	2.01
Sum	20.85	22.48	24.78
Gain (%)	18.5	5.22	3.2

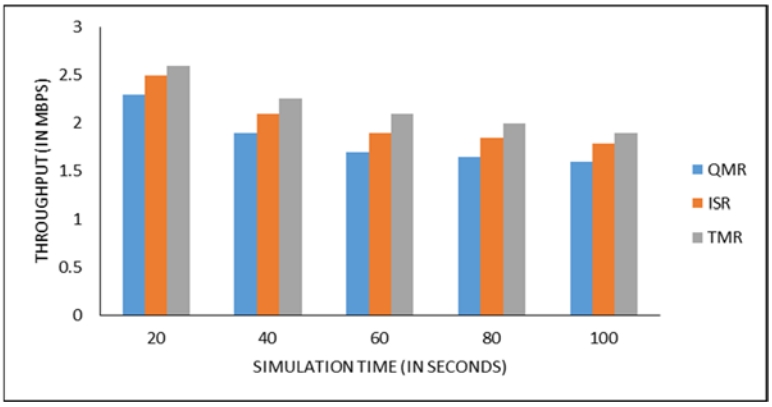

Figure 17. Comparison of throughput with simulation time.

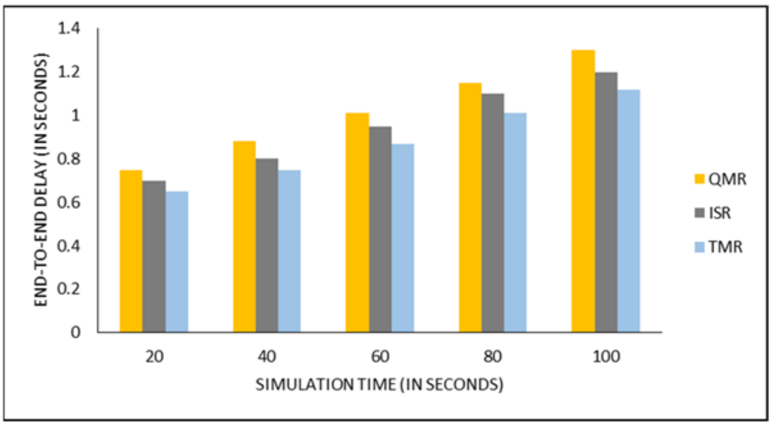

Figure 18. Comparison of end-to-end latency with simulation time.

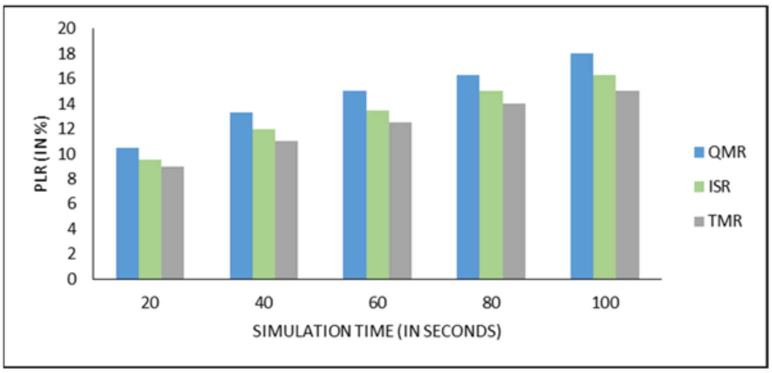

Figure 19. Comparison of the TMR proposed protocol for PLR and the EGSR, ISR.

ISR perform worse than the TMR in terms of routing overhead. As the network receives more traffic over time, the end-to-end delay also increases, as seen in **Figure 19**. Since the TMR, has the least delay because of its path choosing system, the route-finding phase of TMR is started at a slower rate than that of other protocols since TMR has less PLR value.

5. Conclusions

The TMR Multipath Routing Protocol, which we propose in this work, uses, when performing packet transmission tasks to the destination node in VANETs, the round-trip time (RTT). The TMR routing protocol's basic concept is to integrate centralized network intelligence into a single network component in order to speed up packet data delivery while preserving consistency between source and destination. The TMR Multipath Routing Protocol, which we propose in this work, uses, when performing packet transmission tasks to the destination node in VANETs, the round-trip time (RTT). The TMR routing protocol's basic concept is to integrate centralized network intelligence into a single network component in order to speed up packet data delivery while preserving consistency between source and destination. To regulate packet transmission and minimize network load, the majority of data connections between cars should use the Road-Side Unit (RSU).

The TMR routing protocol's basic concept is to integrate centralized network intelligence into a single network component in order to speed up packet data delivery while preserving consistency between source and destination. To regulate packet transmission and minimize network load, the majority of data connections between cars should use the Road-Side Unit (RSU). TMR orders choose the best route with the shortest RTT, which suggests a path with the lowest traffic issues, including data congestion and collisions. To regulate packet transmission and minimize network load, the majority of data connections between cars should use the Road-Side Unit (RSU).

The RTT works based on the TMR routing protocol. The basic concept is to integrate centralized network intelligence into a single network component in order to speed up packet data delivery while preserving consistency between source and destination. To regulate packet transmission and minimize network load, the majority of data connections between cars should use the Road-Side Unit (RSU). TMR prioritizes choosing the best route with the shortest RTT, which suggests a path with the lowest traffic issues, including data congestion and collisions. A threshold value is established as the average RTT and should be less than optimal routes. This system guarantees a direct path to the RSU. TMR orders choose the best route with the shortest RTT, which suggests a path with the lowest traffic issues including data congestion and collisions. A threshold value is established as the average RTT and should be less than optimal routes. This system guarantees a direct path to the RSU. It thus reduces the possibility of packet loss that can occur as high-speed issues vehicles go farther from the RSU. It thus reduces the possibility of packet loss that can occur as high-speed mobility vehicles go farther from the RSU. As a result, as the transmission of alert messages between cars increased, automobile accidents would decline. TMR minimizes data retransmissions, which decreases the amount of data traffic required to quickly send the regular messages, simulations are utilized to assess and contrast the performance of the proposed TMR with other methods. TMR has a greater rate of successfully delivered packets than AOMDV, FF-AOMDV, EGSR, QMR, and ISR, respectively. Additionally, TMR minimizes data retransmissions, which decreases the amount of data traffic required to quickly send the regular messages, simulations are utilized to assess and contrast the performance of the proposed TMR with other methods. TMR has a greater rate of successfully delivered packets than AOMDV, FF-AOMDV, EGSR, QMR, and ISR, respectively. Overall simulation results show that even as the number of cars rises, TMR may greatly improve data transmission performance in VANETs. With regard to specifics, TMR can improve performance with total comparative procedures of 5% to 26%. Future data routing schemes for VANETs should consider the volume of traffic and the dispersion of RSUs.

Author contributions

Conceptualization, BC and MS; methodology, HM; software, RA; validation, SS, BC and MS; formal analysis, RA; investigation, SS; resources, BC; data curation, MS; writing—original draft preparation, BC, RA; writing—review and editing, RA, SS, and HM; visualization, BC; supervision, RA; project administration, SS. All authors have read and agreed to the published version of the manuscript.

Ethics statement

The manuscript is not submitted elsewhere and not under consideration by any other publication.

Funding statement

This research work receives "no external funding".

Conflict of interest

The authors declare no conflict of interest.

References

1. Radisic T, Novak D, Juricic B. Reduction of air traffic complexity using trajectory-based operations and validation of novel complexity indicators. *IEEE Transactions on Intelligent Transportation Systems* 2017; 18(11): 3038–3048. doi: 10.1109/TITS.2017.2666087
2. Shone R, Glazebrook K, Zografos KG. Applications of stochastic modeling in air traffic management: Methods, challenges and opportunities for solving air traffic problems under uncertainty. *European Journal of Operational Research* 2021; 292(1): 1–26. doi: 10.1016/j.ejor.2020.10.039
3. Oosterom M, Babuška R, Verbruggen HB. Soft computing applications in aircraft sensor management and flight control law reconfiguration. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)* 2022; 32(2): 125–139. doi: 10.1109/TSMCC.2002.801357
4. Li W, Dib MVP, Alves DP, Crespo AMF. Intelligent computing methods in air traffic flow management. *Transportation Research Part C: Emerging Technologies* 2010; 18(5): 781–793. doi: 10.1016/j.trc.2009.06.004
5. Alharbi EA, Abdel-Malek LL, Milne RJ, Wali AM. Analytical model for enhancing the adoptability of continuous descent approach at airports. *Applied Sciences* 2022; 12(3): 1506. doi: 10.3390/app12031506
6. Manoharan H. An operative constellation rate for smart safety units using Internet of Things. *Concurrency and Computation: Practice and Experience* 2020; 33(6): e6085. doi: 10.1002/cpe.6085
7. Sivamaran V, Manoharan H, Teekaraman Y, et al. Optimization drive on a flat tire vehicular system for autonomous e-vehicles using network distribution simulations. *Journal of Advanced Transportation* 2022; 2022: 1–8. doi: 10.1155/2022/7028567
8. Yu Q, Wang Y, Jiang X, et al. Optimization of vehicle transportation route based on IoT. *Mathematical Problems in Engineering* 2021; 2021: 1–10. doi: 10.1155/2021/1312058
9. Vojtek M, Kendra M, Zitrický V, Široký J. Mathematical approaches for improving the efficiency of railway transport. *Open Engineering* 2020; 10(1): 57–63. doi: 10.1515/eng-2020-0008
10. Zhang Y, Kou X, Liu H, et al. IoT-enabled sustainable and cost-efficient returnable transport management strategies in multimodal transport systems. *Sustainability* 2022; 14(18): 11668. doi: 10.3390/su141811668
11. Manoharan H, Teekaraman Y, Kuppusamy R, Radhakrishnan A. A novel optimal robotized parking system using advanced wireless sensor network. *Journal of Sensors* 2021; 2021: 2889504. doi: 10.1155/2021/2889504
12. Meneguette RI. A vehicular cloud-based framework for the intelligent transport management of big cities. *International Journal of Distributed Sensor Networks* 2016; 2016: 8198597. doi: 10.1155/2016/8198597
13. Zantalis F, Koulouras G, Karabetsos S, Kandris D. A review of machine learning and IoT in smart transportation. *Future Internet* 2019; 11(4): 94. doi: 10.3390/fi11040094
14. Ouallane AA, Bahnasse A, Bakali A, Talea M. Overview of road traffic management solutions based on IoT and AI. *Procedia Computer Science* 2022; 198: 518–523. doi: 10.1016/j.procs.2021.12.279
15. Qureshi KN, Abdullah AH, Kaiwartya O, et al. A dynamic congestion control scheme for safety applications in vehicular ad hoc networks. *Computers & Electrical Engineering* 2017; 72: 774–788. doi: 10.1016/j.compeleceng.2017.12.015
16. Yuvaraj S, Sangeetha M. Smart supply chain management using Internet of Things (IoT) and low power wireless communication systems. In: Proceedings of 2016 IEEE International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET); 23–25 March 2016; Chennai, India. pp. 555–558.

17. ElMesmary H, Said GAEA. Smart solutions for logistics and supply chain management. *International Journal of Recent Technology and Engineering* 2019; 8(4): 2996–3001. doi: 10.35940/ijrte.D7374.118419
18. Sepulcre M, Gozalvez J, Altintas O, Kremo H. Integration of congestion and awareness control in vehicular networks. *Ad Hoc Networks* 2016; 37: 29–43. doi: 10.1016/j.adhoc.2015.09.010
19. Lee YH, Golinska-Dawson P, Wu JZ. Mathematical models for supply chain management. *Mathematical Problems in Engineering* 2016; 2016: 6167290. doi: 10.1155/2016/6167290
20. Barykin SY, Kapustina IV, Sergeev SM, Yadykin VK. Algorithmic foundations of economic and mathematical modeling of network logistics processes. *Journal of Open Innovation: Technology, Market, and Complexity* 2020; 6(4): 189. doi: 10.3390/joitmc6040189
21. Abbas AW, Marwat SNK. Scalable emulated framework for IoT devices in smart logistics based cyber-physical systems: Bonded coverage and connectivity analysis. *IEEE Access* 2020; 8: 138350–138372. doi: 10.1109/ACCESS.2020.3012458
22. El Kafhali S, Salah K. Performance modelling and analysis of Internet of Things enabled healthcare monitoring systems. *IET Networks* 2019; 8(1): 48–58. doi: 10.1049/iet-net.2018.5067
23. Yu Q, Wang Y, Jiang X, et al. Optimization of vehicle transportation route based on IoT. *Mathematical Problems in Engineering* 2021; 2021: 1312058. doi: 10.1155/2021/1312058
24. Li J, Liu Y, Zhang Z, et al. Towards green IoT networking: Performance optimization of network coding based communication and reliable storage. *IEEE Access* 2017; 5: 8780–8791. doi: 10.1109/ACCESS.2017.2706328
25. Lozano-Garzon C, Montoya GA, Donoso Y. A green routing mathematical model for IoT networks in critical energy environments. *International Journal of Computers, Communications and Control* 2020; 15(4): 3914. doi: 10.15837/ijccc.2020.4.3914