IMPROVED MPR SELECTION ALGORITHM-BASED WS-OLSR ROUTING PROTOCOL

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ABSTRACT

Vehicle Ad Hoc Networks (VANETs) have become a viable technology to improve traffic flow and safety on the roads. Due to its effectiveness and scalability, the Wingsuit Search-based Optimised Link State Routing Protocol (WS-OLSR) is frequently used for data distribution in VANETs. However, the selection of MultiPoint Relays (MPRs) plays a pivotal role in WS-OLSR's performance. This paper presents an improved MPR selection algorithm tailored to WS-OLSR, designed to enhance the overall routing efficiency and reduce overhead. The analysis found that the current OLSR protocol has problems such as redundancy of HELLO and TC message packets or failure to update routing information in time, so a WS-OLSR routing protocol based on improved-MPR selection algorithm was proposed. Firstly, factors such as node mobility and link changes are comprehensively considered to reflect network topology changes, and the broadcast cycle of node HELLO messages is controlled through topology changes. Secondly, a new MPR selection algorithm is proposed, considering link stability issues and nodes. Finally, evaluate its effectiveness in terms of packet delivery ratio, end-to-end delay, and control message overhead. Simulation results demonstrate the superior performance of our improved MR selection algorithm when compared to traditional approaches.

KEYWORDS

Ad hoc Network, VANETs, OLSR Routing, MPR, Node Residual Energy.

1. INTRODUCTION

Vehicle Ad Hoc Networks (VANETs) have become a game-changing technology with the potential to greatly improve traffic management, road safety, and vehicular communication in general [1], [2], [3]. To transmit vital information including traffic conditions, safety alerts, and real-time navigation data, vehicles in VANETs communicate with one another and with roadside infrastructure. Numerous routing methods have been suggested to enable effective data dissemination in VANETs, with the Wingsuit Search-based Optimised Link State Routing Protocol (WS-OLSR) emerging as a popular option due to its scalability and adaptability to highly dynamic vehicular environments [4].

Despite the promising attributes of WS-OLSR, the selection of MultiPoint Relays (MPRs) remains a persistent challenge in the protocol, as underscored by previous studies [5] [6]. While these research endeavours have made notable contributions to the field, they often fall short of comprehensively addressing the distinct hurdles posed by weighted links, dynamic network topologies, and scalability issues inherent to WS-OLSR [7].

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MPRs hold a pivotal responsibility in efficiently routing control messages and data packets throughout the network. Conventionally, MPRs have been designated based on fixed criteria, frequently reliant on a vehicle's position within the network graph [8] [9]. However, these conventional MPR selection algorithms frequently lack the agility required to cope with the dynamic nature of Vehicular hoc Networks (VANETs). In VANETs, vehicles are in perpetual motion, operating at diverse speeds and densities, introducing a layer of complexity that static MPR selection algorithms are ill-suited to manage.

The repercussions of suboptimal MPR selections in VANETs are substantial, leading to elevated control message overhead, prolonged end-to-end data transmission delays, and reduced packet delivery rates which ramifications significantly impede network performance and efficiency. Given these distinct challenges and constraints found in existing research, a thorough review and analysis are warranted to delineate this paper from prior work. This paper seeks to bridge this gap by presenting an innovative approach or algorithm tailored to address the intricacies of weighted links, dynamic topologies, and scalability concerns that are inherent in WS-OLSR. In so doing, it provides a fresh and novel perspective, offering inventive solutions to MPR selection in VANETs, thereby distinguishing itself from prior research and necessitating a comprehensive review.

In reference [10], various efforts have been dedicated to improving the OLSR routing protocol by optimizing the crucial HELLO and TC messages. These messages are fundamental for neighbour discovery and topology dissemination within OLSR networks. The research conducted in this reference delves into strategies for reducing the overhead associated with these messages while ensuring their continued effectiveness [11]. The primary aim here is to minimize unnecessary message transmission and enhance the efficiency of OLSR through message format optimization. Additionally, reference [12] introduces a noteworthy approach aimed at sustaining the stability of multi-hop links. This approach involves actively adding and managing routes to achieve and maintain route stability. By doing so, the protocol seeks to offer consistent and reliable communication paths, ultimately leading to improved packet delivery and reduced disruptions in wireless networks. References [13] and [14] also contribute to the discussion by proposing new ideas regarding the selection algorithm for the MultiPoint Relays (MPR) set in the OLSR routing protocol. These algorithms incorporate a diverse array of factors into their selection processes, with overarching objectives of elevating data transmission success rates, enhancing network stability, and mitigating issues such as packet loss, network overhead, and latency.

In the selection of the MPR set, various factors such as node movement state, connection time, node-link rate change rate, link congestion degree and node remaining energy are considered to improve the success rate of data transmission and network stability and reduce the packet loss rate, network overhead and latency purposes. In Reference [15], [16] refers to the intelligent cluster algorithm to optimize the application of VANET self-organizing network, but its biggest defect is that this kind of algorithm has high requirements on the computing power of VANET, and the start-up time is long, which can the practical scope of the application is very limited.

To sum up, most of the current optimization schemes for OLSR at home and abroad focus on the optimization of the MPR selection algorithm and the optimization of the optimal solution through the cluster solution. The overhead is greater and the response sensitivity is reduced. Therefore, considering the above factors and the characteristics of the OLSR protocol itself, to achieve the purpose of reducing network overhead, improving network stability and increasing network survival time. In this study, we have presented an enhanced MPR selection algorithm tailored to the WS-OLSR routing protocol in VANETs. The improved MPR selection algorithm, which integrates the link stability problem and takes the remaining energy (survival time) factor into consideration, the flooding cycle of TC messages is controlled according to the update frequency of the MPR set. By accounting for dynamic network conditions, our algorithm substantially improves the protocol's performance, leading to better packet delivery ratios, reduced delays, and decreased control message overhead.

These enhancements make our algorithm a valuable contribution to the field of VANET research, promoting safer and more efficient vehicular communication. WS-OLSR extends OLSR by introducing link weights that reflect various network metrics such as link quality, bandwidth, or other relevant factors.

This innovation enhances the protocol's capability to make informed routing decisions in dynamic wireless environments. Future work may explore the integration of machine learning techniques to further optimize MPR selection in highly dynamic VANET environments.

2. OPTIMIZATION OF OLSR ROUTING PROTOCOL

The primary objective of routing protocols like OLSR is to establish and maintain efficient data paths between nodes in a network. OLSR achieves this by proactively exchanging topology information among neighbouring nodes, which allows each node to build a routing table based on the most up-to-date network state [17] [18], [19]. However, while OLSR exhibits many desirable characteristics, it is not without its challenges and limitations.

Optimized Link State Routing (OLSR) is a routing protocol mainly used in VANET networks [20], [21]. In the traditional link-state routing algorithm, each node in the network broadcasts its link-state packets to other nodes, and this process is called flooding. Each link state packet contains the link identification and cost that the node is connected to, and finally, after flooding, each node in the network can get the same network topology map. OLSR optimizes the traditional algorithm, and the core mechanism here is the selection of the MPR set and the working mechanism of MPR [22], [23], [24].

A small number of nodes are selected as MPR nodes, and only MPR nodes are allowed to broadcast and flood control messages, the to reduce the number of flooding times and the number of flooding nodes, thereby reducing the amount of information transmission and reducing network overhead [25]. OLSR is suitable for large-scale, high-density scenarios.

For the optimization of OLSR, two optimization schemes are given in this paper. One is to control the broadcast period of messages through topology changes, and the other is to propose a new MPR selection algorithm for the defects of traditional MPR selection algorithms. Through the above two optimization schemes, based on the original OLSR protocol, the WS-OLSR protocol has better performance, such as lower routing overhead and energy consumption, and higher message delivery rate.

2.1. Broadcast Mechanism of HELLO Message

The broadcast mechanism of HELLO messages plays a critical role in various networking protocols, including routing protocols like OLSR (Optimized Link State Routing), where HELLO messages are employed to establish and maintain neighbour relationships among network nodes. OLSR maintains routing information by regularly broadcasting HELLO messages and MPR sets forwarding TC messages by nodes in the network. HELLO messages are used to establish local link information databases and adjacent node information databases [26], [27], [28].

However, when the network topology does not change much and the node status is stable, if the message is sent according to the original broadcast cycle, unnecessary operations will occur, resulting in a large amount of redundant network overhead and energy consumption [29]. If the network topology changes frequently, the network fluctuates greatly, and the node status is unstable, the originally set message-sending interval will make OLSR unable to update the network status in time, resulting in network performance degradation.

Therefore, this paper considers defining the topology state of the network through node information and controlling the flooding cycle of messages through the topology state of the network.

This research examines the relative mobility and link status of each node in the network and all of its one-hop neighbour nodes to assess the network topology state. Because there are few significant three-dimensional dynamic changes in the working scene and most of the changes are small, the mathematical modelling of the VANET assumes that it is moving on the same horizontal plane. A three-dimensional coordinate system is therefore not established.

a) Relative mobility of nodes:

Define node i as any node in the network, and j as any one-hop neighbour of node i, then the moving speed of node j relative to node i at time t1 is:

$$V_{ij} = \sqrt{(V_{ix} - V_{jx})^2 + (V_{iy} - V_{jy})^2} \tag{1}$$

Where, V_{ix} is the velocity of node i in the horizontal direction in the coordinate system, V_{iy} is the velocity of node i in the vertical axis direction in the coordinate system; V_{jx} is the velocity of node j in the horizontal direction, and V_{jy} is the velocity of node j in the vertical direction.

The relative distance of node j relative to i at time t1 is:

$$Sij = \sqrt{(Xi - Xj)^2 + (Yi - Yj)^{\,2}} \tag{2}$$

Where Xi and Xj are the position changes of node i and node j in the horizontal direction in the coordinate system, and Yi and Yj are the position changes of node i and node j in the vertical direction in the coordinate system; T is the flooding period of node i, t1 is defined as the time before T, and t2 is the time after T, then the moving speed of node j at time t2 relative to node i is Vij', then node j at time t2 moves relative to node i. The distance is Sij.

The speed change and distance change in the T time range are expressed as:

$$\Delta V = |Vij - Vij'| \tag{3}$$
$$\Delta S = |Sij - S'ij| \tag{4}$$

Define M as the relative mobility of nodes, then M is expressed as:

$$M = a\Delta V + b\Delta S \tag{5}$$

Where a and b are weights, and a+b=1. Define a count variable Na of node i and the mobility threshold m between nodes. The initial value of Na is 0. When the relative mobility M>m between node i and node j, the value of Na is increased by 1.

b) Node link state, the node link state is defined by:

$$N_{Links} = N_{nei} + N_{sys} + N_{Asym} \tag{6}$$

Where N_{Links} is the current link status of the node, and the change of the network topology of the surrounding nodes is inferred by monitoring the changes in the node's information table. B is the change number (increase and decrease) of neighbour nodes around the node within a HELLO message sending time interval; N_{Asym} is the number of symmetrical one-hop nodes is newly added by a node within a HELLO message sending time interval, and N_{Asym} is the number of symmetrical one-hop nodes within a HELLO message sending time interval. The number of symmetric one-hop nodes reduced by nodes. Because neighbours change and links become asymmetrical, the network needs to be detected again, and generally three HELLO messages are sent. Therefore, N_{nei} and N_{Asym} here are the average values of the interval of 3 HELLO messages, and only one notification is required for the link state to become symmetrical, so N_{Asym} is the current value.

Based on the relative mobility and link status of the above nodes, the network topology changes around the nodes are obtained, so the calculation formula for defining the network stability is:

$$N_S = 0.3 \times N_\alpha + 0.7 \times N_{Links} \tag{7}$$

The difference in the coefficients in the formula is because the link status reflects the network status more clearly, while the mobility status reflects more the physical level node movement status, and more is predictive function. There may be no change in the network topology level when the node mobility fluctuates, but if this situation continues, the change in the network topology level will appear predictably, and it will play a role of early warning and monitoring at this time. However, in more cases, it is caused by link state changes or both occur at the same time.

Define the sending interval increment ΔH=1s, $\mathrm{H_t}$which is the default HELLO message sending interval of OLSR routing protocol, which is 2s. $\mathrm{H_{is}}$ is defined as the adaptive HELLO message sending interval. This paper comprehensively considers the impact of links and mobility on Ns and divides His into three intervals. When Ns=0, the network state is considered to be in a relatively stable state, and $\mathrm{H_{is}} = \mathrm{H_t} + \Delta\mathrm{H}$; when Ns=1, the network is considered to be in a normal state, $\mathrm{H_{is}} = \mathrm{H_t}$; when Ns≥2, the network is considered to be in a state of violent fluctuations, in order to update the network status in time, set $\mathrm{H_{is}} = \mathrm{H_t} - \Delta\mathrm{H}$ [23]; So His is expressed as:

ΔH [23]; So the expression of His is:

$$H_{is} = \begin{cases} Ht + \Delta H & 0 \le Ns < 1 \\ Ht & 1 \le Ns < 2 \\ Ht - \Delta H & 2 \le Ns \end{cases} \tag{8}$$

In order to take into account, the hysteresis of His changes caused by the existence of intermediate states in the process of network state changes, the expression is optimized:

$$H_{is} = \begin{cases} Ht + Ns \times \Delta H & 0 \le Ns < 1 \\ Ht - (Ns - 1)\Delta H & 1 \le Ns < 2 \\ Ht - \Delta H & 2 \le Ns \end{cases} \tag{9}$$

2.2. TC Message Flooding Mechanism

The TC (Topology Control) message flooding mechanism is a crucial component in proactive routing protocols like OLSR that rely on the exchange of network topology information to establish and maintain efficient routing paths. TC messages are used to disseminate information about a node's network neighbourhood, allowing other nodes to construct and update their routing tables. The TC message is different from the broadcast mechanism of the HELLO message and the communication range of one hop.

The existence of the TC message is to maintain the topology of the entire network, so its message forwarding range is the entire network, and the MPR node set is responsible for forwarding. The HELLO is longer. To ensure the timeliness of the TC message, the valid time of the TC message is longer than that of the HELLO message.

Therefore, to maintain the sending interval of the TC message, it is only necessary to monitor the change of the MPR set to know the change of the network topology. TCt is the default flooding period, which is 5s. Define the TC message flooding period after maintenance as TCis, define M as the counting unit, and set the initial state flooding period as TCt. When the MPR set does not change, set M=0, Define the current interval as TCtcur, let the next message flooding period $\mathrm{T_{Cis}}=\mathrm{T_{Ctmin}}+1$, until the TCis reaches the maximum threshold value, set the maximum sending interval as 8s; when the MPR set changes (node-set, link increase or decrease), set M=1, let $\mathrm{T_{Cis}}=\mathrm{T_{Ctmin}}$, $\mathrm{T_{Ctmin}}$ be set to 4s. Therefore, the expression of TCis is:

$$\mathrm{T_{Cis}} = \begin{cases} \mathrm{T_{Ctcur}} & \mathrm{M} = 0 \\ \mathrm{T_{Ctmin}} & \mathrm{M} = 1 \end{cases} \qquad (10)$$

3. PROPOSED METHOD

In OLSR routing, the MPR mechanism is its core idea. A node selects an MPR node set through its one-hop neighbour nodes and two-hop neighbour nodes. All nodes can receive the message, but only the nodes selected as the MPR set can forward the message to this node. The information required for the calculation of the MPR set is obtained through the periodically broadcast HELLO message. Note that there is a willingness option in the HELLO packet data. A node carrying willing_never will never be elected as an MPR by any node.

A node with willing_always is preferred to be elected as MPR. The default is willing_default. The current traditional MPR selection algorithm is proposed in the standard OLSR protocol.

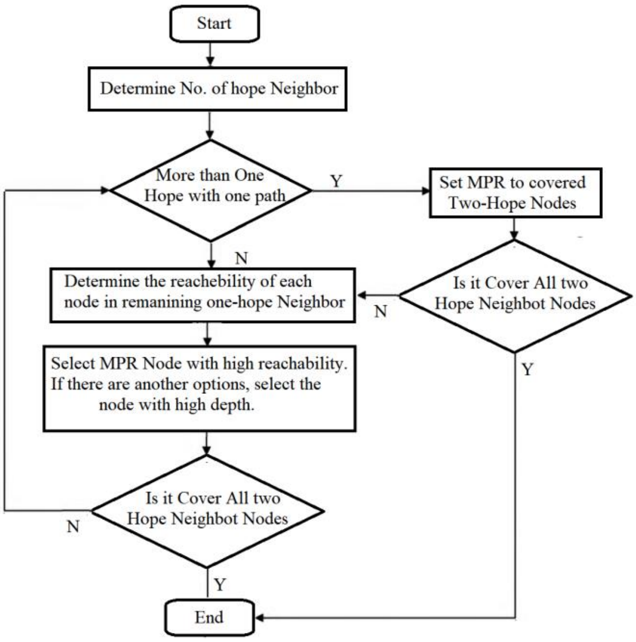


Figure 1. Traditional MPR selection algorithm process

This is a wingsuit flying search algorithm [4], which designs an MPR set that can ensure that a node can reach all strictly symmetrical two-hop neighbour nodes through the MPR node relay whose willingness is not willing_ never. The algorithm flow is shown in Figure 1.

At the same time, there are still some problems in the traditional MPR selection algorithm, such as redundancy, the selected MPR set is not optimal, unnecessary network overhead is generated, the energy consumption of MPR is not considered, and the stability of nodes selected as MPR is not considered. This paper proposes the improve OLSR protocol to based on the selection factors such as node energy, link and mobility are considered. The selection method of MPR optimized based of the original algorithm is as follows.

3.1. Model Formulation

In the OLSR routing protocol, the MPR mechanism is the core mechanism, and choosing a suitable MPR node will directly affect the routing overhead, energy consumption and network reliability. Therefore, to establish reliable routing and ensure good network performance, appropriate MPR nodes must be selected. The high mobility of nodes will make link on-off and information exchange more frequent compared with the general mesh network, resulting in higher energy consumption. Therefore, when considering the selection of MPR nodes, factors such as node residual energy and node-link conditions should be considered. To comprehensively consider the above factors, make the selected MPR as stable as possible and reduce the probability of MPR switching.

a) For the node survival problem, the survival time of the node can be predicted by the remaining energy E_r of the node. The relevant meanings are as follows:

$$\eta = \frac{E_r}{E_0} \tag{11}$$

Where, η is the percentage of the current remaining energy to the total energy.

b) For the link problem of the node, the change of the link of the node is introduced.

It is necessary to ensure that the MPR set forwards TC messages, only symmetric nodes can be selected as the MPR set. It is defined as follows:

$$N_c = N_{add} + N_{del} \tag{12}$$

$$\delta = \frac{N_c}{N_n} \tag{13}$$

Where N_c is the number of strictly one-hop symmetric nodes added or decreased within the interval of the current HELLO message of the node, and N_c is the current total number of symmetric nodes of the node. The number of hop symmetric nodes, δ is the change rate of symmetric nodes, which reflects the stability of node links.

c) The problem of node-link transmission quality [22], the link transmission quality (LTQ) between nodes is calculated by the message ratio of the HELLO message sent by the neighbour node within a certain period. To evaluate the ForwardLink (FL) and the value of the quality of the reverse link, that is, the neighbour link (NL) as follows:

$$F\mathrm{L} = \frac{No.of\ message\ j\ received\ from\ i}{No.of\ message\ i\ sent\ to\ j} \tag{14}$$

$$N\mathrm{L} = \frac{No.of\ message\ i\ received\ from\ j}{No.of\ message\ j\ sent\ to\ i} \tag{15}$$

Where the quasi-MPR node i, the number of HELLO messages that i can obtain is only "the number of HELLO messages sent by i to j" and "the number of HELLO messages sent by i received by j".

Then F_L and N_L are determined, and L_{TQ} cannot be calculated.

Therefore, the optimized method can be converted into the following method to obtain L_{TQ}.

$$F\mathrm{L} = \frac{No.of\ message\ i\ received\ from\ j}{No.of\ message\ i\ sent\ to\ j} \tag{16}$$

$$N\mathrm{L} = \frac{No.of\ message\ j\ received\ from\ i}{No.of\ message\ j\ sent\ to\ i} \tag{17}$$

$$\mathrm{LTQ} = \mathrm{FL} \times \mathrm{NL} \tag{18}$$

According to the three variables defined above, it is further defined as the overall impact factor of MPR determination, which is characterized by weighted calculation. Since the change rate of δ symmetrical nodes is negatively correlated with the value, the specific expression is:

$$P_{\mathrm{L}} = a_1\eta - a_2\delta + a_3(\mathrm{average}(L_{\mathrm{TQ2}}) + L_{\mathrm{TQ1}}) \tag{19}$$

where a, b, and c are the weight coefficients corresponding to the node attributes, and a_1+a_2+a_3=1, and the values are adjusted for different directions of the network. L_{TQ1} is the link transmission quality value between the current node and the node performing the MPR set calculation, and $\mathrm{average}(L_{\mathrm{TQ2}})$ is the link transmission quality between the current node and its strictly one-hop symmetric node (that is, the strict two-hop symmetric node of the node performing the MPR set calculation) the average of the values.

According to the P_L value, the candidate MPR nodes are sorted from high to small. The node with a higher P_L value has higher residual energy, which reflects that its survival time will be longer, and the link stability and link transmission quality are relatively high. It can be seen that the candidate nodes with higher P_L values are easier and more suitable to be selected as MPR nodes. In this paper, the network focuses on the node survival time, so the proportions of a, b, and c are determined to be 0.4, 0.3, and 0.3, respectively.

3.2. WS-MPR Selection Algorithm

The core idea of the improved algorithm proposed in this paper is: that in in the topology structure, when node i selects an MPR node, a priority decision relationship is set, and the priority of node survival status and link stability is greater than the priority of node depth. When selecting, first determine the size of the S_L value, followed by the node depth, and then select the MPR in turn. The algorithm flow is shown in Figure 2.

Topology-Based Selection: The WS-MPR Selection Algorithm focuses on choosing MultiPoint Relays (MPR) within the network topology. When a specific node (denoted as "node i") needs to select an MPR node, it does so by establishing a priority order based on certain factors.

Priority Criteria: The core idea behind this algorithm is to establish a set of priority criteria for MPR selection. Two primary factors are considered to determine the priority of MPR nodes:

Node Survival Status: The algorithm prioritizes MPR nodes based on their ability to maintain network connectivity. This means that nodes with a higher likelihood of staying active and reliably forwarding messages take precedence.

Link Stability: The stability of communication links is another critical factor. The algorithm emphasizes selecting MPR nodes that offer stable and dependable connections.

Node Depth: In addition to the aforementioned priority criteria, the algorithm considers the depth of nodes within the network topology. Node depth represents the number of hops it takes to reach a specific node. However, in this algorithm, node depth is a secondary consideration, meaning that it holds less priority than node survival status and link stability.

Selection Process: The actual MPR selection process follows a sequential order. The main steps are as follows:

Step 1: Initialization: Begin with an empty set to store the selected MPR nodes (Mi).
Step 2: Path Value and Node Depth Calculation: Calculate both the "path value" and the node depth for all nodes in the one-hop neighbour set (denoted as Q1).
Step 3: Selecting MPRs: Select MPR nodes from Q1 following a specific protocol. Firstly, nodes with a unique path to a two-hop neighbour are chosen and added to the MPR set (Mi). These selected nodes are also responsible for covering the nodes in the two-hop neighbour set (Q2). After this step, the algorithm checks if Q2 is empty; if it is, the selection process ends. Otherwise, the process continues to the next step.
Step 4: Adding Remaining MPRs: In this step, the algorithm adds nodes from the remaining set in Q1. It prioritizes nodes with the largest path value. In cases where multiple nodes have the same path value, the algorithm considers their node depth (D(y)) and selects the one with the greatest depth. If there are still multiple nodes with equal values, the algorithm proceeds to select one and removes the nodes it covers from Q2. The process iterates until Q2 becomes empty.

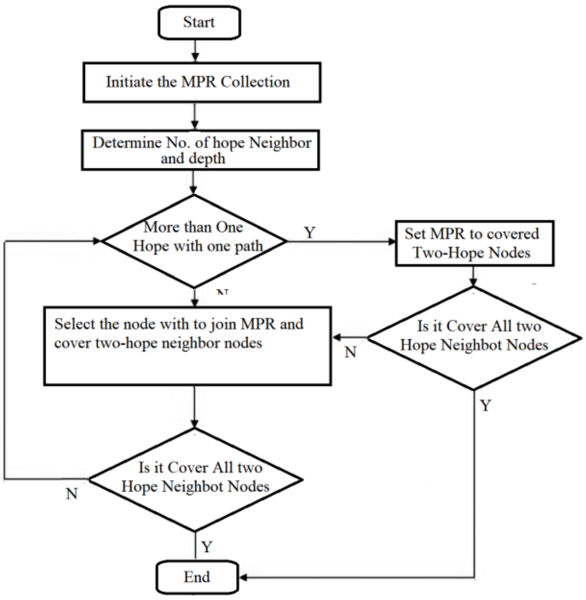


Figure 2. WS-MPR selection algorithm flow

This algorithm aims to optimize the selection of MPR nodes in the network by prioritizing nodes that are likely to maintain connectivity and have stable communication links. It also takes into account node depth as a secondary factor. This approach helps reduce redundancy and unnecessary network overhead while improving overall network performance and efficiency.

4. RESULT AND DISCUSSION

4.1. Simulation Parameters

This article uses the NS2 simulation software on the Linux platform to set up 5 simulation scenarios, each node has the same computing power, and the communication range and other information parameters are also the same. A detailed explanation of the network simulation parameters as described in Table 1:

Network Simulator: The researchers employed NS2 simulation software with a specific version, NS 3.29. NS2 (Network Simulator 2) is a widely used open-source network simulation tool for modelling and analysing the behaviour of computer networks. In this case, NS3.29 was utilized to set up and run the network simulations.

Operating System: The simulations were conducted on the Ubuntu 18.04 operating system. Ubuntu is a popular Linux distribution, known for its stability and suitability for various computational tasks, including network simulation.

Transport Protocol: The transport protocol used for the simulations was UDP (User Datagram Protocol). UDP is a connectionless and lightweight transport protocol that is often used for applications where low latency and minimal overhead are required, making it suitable for real-time and multimedia applications.

Number of Nodes: The simulations involved a variable number of nodes, ranging from 20 to 200. This parameter explores how the proposed approach performs in networks of different scales, from relatively small to significantly larger ones.

Radio Propagation Mode: The radio propagation mode was set to "Ground, two dimensions." This mode likely simulates a two-dimensional ground-based radio propagation environment, which is relevant for terrestrial wireless communication scenarios.

Fixed Speed: The nodes in the simulation had a fixed speed of 25 meters per second (m/sec). This fixed speed could mimic the movement of nodes in scenarios where vehicles or mobile devices maintain a consistent speed.

Packet Size: The size of the packets used in the simulations was 512 bytes. Packet size is a critical parameter, as it affects the efficiency of data transmission and can impact network performance.

Mobility Model: The mobility model chosen for the simulations was the "Random Waypoint" model. In this model, nodes move randomly within the simulation area, pausing at waypoints, which is commonly used to represent the unpredictable movement of mobile devices or vehicles.
Simulation Time: The simulations were run for 200 seconds. This timeframe represents the period over which the researchers observed and analysed network behaviour and performance.

Simulation Area: The simulation area was defined as 950 meters by 950 meters (950 m x 950 m). This parameter specifies the spatial extent of the simulated network environment and is important for understanding network coverage and behaviour in a specific area.

MAC Protocol: The Medium Access Control (MAC) protocol used in the simulations was IEEE 802.11. IEEE 802.11 is a widely adopted standard for wireless local area networks (WLANs) and is commonly used for wireless communication in various scenarios.

Table 1. Simulation parameters

Parameters	**Description**
Network Simulator	NS 3.29
Operation System Ubuntu	18.04
Transport Protocol	UDP
Number of Nodes	20-200
Radio Propagation Mode	Ground, two dimensions,
Fixed Speed	25 m/sec
Packet Size	512 bytes
Mobility Model	Random Waypoint
Simulation Time	200 seconds
Simulation Area	950 m x 950 m
MAC Protocol	IEEE 802.11

The operating mechanism of the OLSR protocol determines that its routing overhead is destined to be relatively large compared with other routing protocols. The routing overhead refers to the routing cost on the path where the data packet is sent from the source node to the destination node. The influencing factors are as follows: Protocol-related factors such as line occupancy rate, data transmission and reception volume, hop count, etc. Different dynamic routing protocols will choose one or more of the above factors to calculate the routing overhead. The choice here is to calculate the total sent and received effective data packets as a measure of overhead. Compared with the traditional OLSR protocol, the WS-OLSR protocol has a small number of nodes (before 80 nodes), that is, when the topology structure and changes are relatively simple, the overhead of the two routing protocols is very close, and the difference is not large, as shown in Figure 3.

When the number of nodes is large and the topology structure and changes are relatively complex, the MOLSR protocol has obvious advantages. The modified WS-OLSR is aimed at controlling the sending time of HELLO messages and TC messages through topology changes. Compared with the original OLSR, the routing overhead of the improved WS-OLSR is reduced by at least 10%.

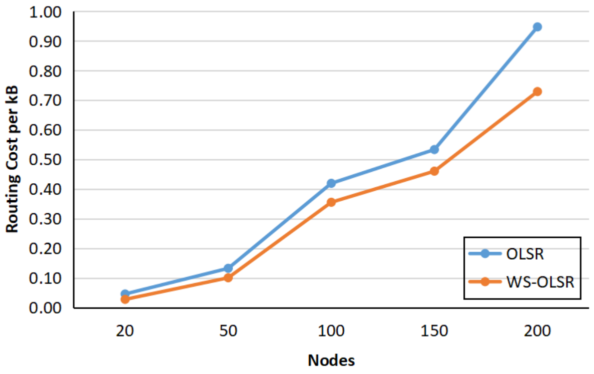


Figure 3. Comparison of routing overhead between OLSR protocol and WS-OLSR protocol

4.2. Packet Delivery Rate (PDR)

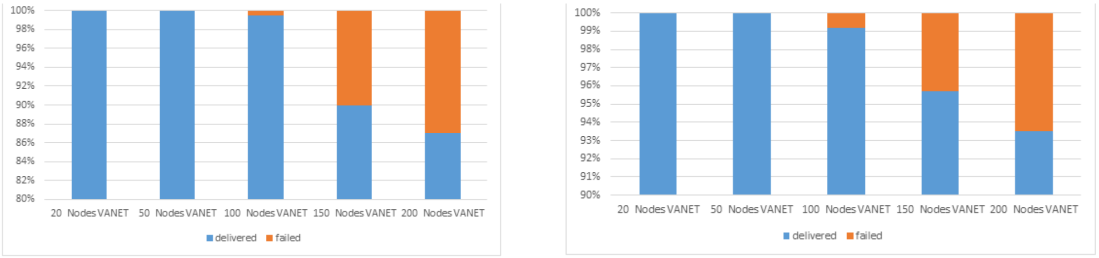
The Packet Delivery Rate (PDR) is a fundamental metric used to evaluate the performance of routing algorithms in a network [30] [31]. It quantifies the efficiency of data packet transmission from a source node to a destination node. This metric is expressed as a ratio, specifically, the number of data packets successfully received by the destination node divided by the total number of data packets sent by the source node. The resulting value is typically a fraction between 0 and 1, and it is a crucial indicator of how well a routing algorithm performs in terms of delivering data reliably.

A Packet Delivery Rate of 1 (or 100%) indicates that every data packet sent from the source node has successfully reached the destination node. This represents an ideal scenario where no data is lost in transit, and network performance is at its best.

A Packet Delivery Rate of less than 1 indicates that some data packets were lost or not successfully delivered. The closer the rate is to 1, the better the network's performance, as it signifies a higher proportion of successful deliveries.

Packet Delivery Rate is an essential metric for assessing the effectiveness of routing algorithms. In the context of the research paper, it's used to evaluate the performance of two routing protocols: OLSR (Optimized Link State Routing) and WS-OLSR (Weighted Sum Optimized Link State Routing). By comparing the Packet Delivery Rates of these two protocols, the researchers can determine which one is more efficient in terms of delivering data packets.

Figure 4 in the paper likely presents a graphical comparison of the Packet Delivery Rates of OLSR and WS-OLSR. Such a comparison allows the researchers to visually assess how these protocols perform concerning successful data packet delivery. An improvement in the Packet Delivery Rate, moving it closer to 1, indicates better network performance and more reliable data transmission, which is a key goal in designing and evaluating routing algorithms for network communication.



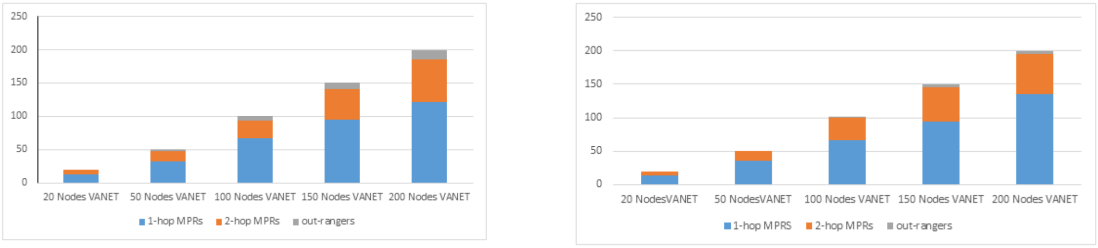
(a) (b)

Figure 4. Comparison of packet delivery rates between a) OLSR protocol and b) WS-OLSR protocol

The success rate of the WS-OLSR protocol is much higher than that of the OLSR protocol, especially when the number of nodes is large and the topology changes are complex. In the MOLSR protocol, the redundancy of message flooding is reduced on the based on the original protocol, and message congestion is reduced to a certain extent. In the SL-MPR selection algorithm, link changes and node energy issues are taken into consideration to ensure improved link utilization and stability. Simulations show that the packet delivery rate of the protocol is significantly improved.

4.3. Efficiency of Routing

The efficiency of routing of the protocol here is to count the remaining energy of the fixed node in multiple experiments and obtain the difference from the initial energy value of the node. It can be seen from the energy consumption comparison diagram of the protocols in Figure 5 that the efficiency of routing of the two protocols is almost the same when the number of nodes is small, but the energy consumption of the WS-OLSR protocol is better than that of the traditional OLSR protocol when the number of nodes is large. This is because when the topology is complex, the appropriate MPR node selection reduces the network overhead and prolongs the node survival time and the adaptive HELLO broadcast message and TC control message flooding can more effectively reduce the loss of node redundancy. The remaining amount of energy reflects the survival time of the node.



(a) (b)

Figure 5. Comparison of efficiency of routing between a) OLSR protocol and b) WS-OLSR protocol

While the performance of any protocol or optimization can vary depending on specific scenarios, there are some considerations on how the enhancements may fare in real-world VANET applications:

Topology Dynamics: In real-world VANETs, the road network is dynamic, with vehicles constantly moving, entering, and leaving the network. The proposed optimization scheme, designed to handle frequent topology changes, is expected to perform well in such scenarios by efficiently adapting to network fluctuations.

Traffic Conditions: The performance of the optimization scheme may vary based on traffic density, which can significantly impact communication reliability. During congested traffic, the scheme's ability to optimize message routing is crucial for maintaining connectivity.

Interoperability: Real-world VANETs often involve vehicles from various manufacturers, each potentially using different communication equipment. The ability of the proposed upgrades to interoperate seamlessly with a variety of VANET devices is critical for practical success.

Communication Range: VANETs encompass both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. The scheme's ability to adapt to varying communication ranges and handle communication with roadside infrastructure is a key consideration.

5. CONCLUSION

This paper has effectively tackled the limitations inherent in the original OLSR protocol, particularly addressing the inflexibility of its broadcast message mechanism and the limited considerations in its MultiPoint Relays (MPR) selection algorithm. The introduction of an optimization scheme for OLSR has been pivotal in enhancing the protocol's adaptability during network communication, with a specific focus on minimizing the adverse effects of frequent topology changes on its performance. In the realm of optimizing the MPR selection algorithm, this research has diligently accounted for various influencing factors in the selection of MPR nodes. The extensive array of simulation experiments conducted has provided substantial evidence that the refined WS-OLSR protocol outperforms the traditional OLSR protocol, significantly elevating overall network performance. It is crucial to recognize that communication and routing in Vehicular Ad-Hoc Network (VANET) environments are intrinsically intricate and multifaceted. While this paper has concentrated on addressing pivotal facets of these challenges, we acknowledge that there exists a plethora of other factors that necessitate comprehensive exploration in future networking research endeavours. As such, future research in the domain of VANET networking may consider the following directions:

Dynamic Traffic Management: Investigating adaptive mechanisms for managing traffic within VANETs to optimize routing and reduce congestion.

Security and Privacy Enhancements: Developing robust security measures and privacy preservation techniques for VANETs, particularly in the context of vehicular communication.
Energy-Efficient Protocols: Exploring energy-efficient routing and communication protocols to prolong the lifespan of battery-powered vehicles and infrastructure.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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