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A Novel Dynamic Link Prediction Protocol for Frequent Link Disconnections in Vehicular Ad Hoc Networks

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Abstract – Vehicular Ad hoc Networks (VANETs) face challenges in maintaining communication links due to their large network sizes and rapidly changing topologies. Frequent link disconnections can impact the performance of vehicular applications, which are crucial for Intelligent Transport Systems (ITS). The objective of the research is to develop a dynamic link prediction protocol (NDLP) that can predict when a link is likely to become unavailable. By predicting link disconnections in advance, the protocol aims to reroute data packets through alternative paths to ensure uninterrupted communication. In this paper, a novel dynamic link prediction protocol (NDLP) is proposed to determine the duration of availability of the current path. This protocol predicts the duration of current path availability, aiming to pre-emptively predict connection breakdowns and reroute data packets via alternate paths. The proposed methodology involves the use of Newton's divided difference interpolation to assess the presence of active links to adjacent nodes. This technique employs historical data or real-time measurements to predict the future state of links. The primary focus is on predicting link disconnections before they occur and pre-emptively rerouting packets using an alternative path. The estimation of the time of link breakage and the ability to select the best route before the link breakage is analysed. Simulation results have proven the effectiveness of NDLP protocol with its counterpart protocols in terms of delay, packet delivery ratio and throughput.

Index Terms – Vehicular Ad Hoc Networks, Link Disconnections, Link Discovery, Link Prediction, Novel Dynamic Link Prediction, NDLP.

1. INTRODUCTION

Vehicular Ad hoc Networks (VANET) have become an important technology for enabling efficient communication and coordination among vehicles on the road. VANETs facilitate number of applications such as traffic monitoring, collision prevention, and infotainment services, all of which rely on reliable and continuous connectivity between vehicles [1]. However, the dynamic nature of vehicular mobility presents significant challenges in maintaining stable links, as frequent link disconnections can occur due to factors such as high vehicle speed, obstacles, signal interference, and congestion.

The frequent link disconnection issue poses a considerable obstacle to the effective functioning of VANETs [2]. It can result in communication disruptions, packet loss, increased latency, and reduced overall network performance. To address these challenges, several link prediction methods have been designed in the literature. Link prediction aims to anticipate the future state of links depending on previous data and other relevant parameters [3].

Existing link prediction protocols for VANETs primarily focus on predicting link stability depending on the vehicle's current location, velocity, and trajectory [4]. However, these approaches often overlook the temporal aspects and fail to capture the underlying causes of link disconnections. Furthermore, they do not adjust to the evolving network conditions, limiting their effectiveness in highly dynamic VANET environments.

In this research, a Novel Dynamic Link Prediction Protocol (NDLP) is proposed specifically to tackle the problem of frequent link failure in VANETs. The NDLP leverages historical data on link connectivity patterns to identify common factors contributing to link failures, such as obstacles, congestion, and signal interference [5]. By

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analysing this data, the protocol builds a prediction model that estimates the likelihood of link failures in the future.

The NDLP employs a distributed prediction mechanism where vehicles exchange prediction information with their neighboring vehicles. This information includes the estimated probabilities of link disconnections, enabling vehicles to make proactive decisions regarding route selection and data forwarding [6]. Additionally, the NDLP dynamically adapts its prediction model based on real-time observations, allowing it to adjust to changing network conditions and improve the accuracy of link predictions [7].

The key objective of this proposed work is to analyse the effectiveness of the proposed NDLP in mitigating the impact of frequent link disconnections in VANETs. Through extensive simulations in various VANET scenarios, the working of NDLP is assessed in view of delay, packet delivery ratio, and throughput. By analyzing the results with current link prediction protocols, the superiority of NDLP is demonstrated effectively in handling frequent link disconnections and enhancing the overall reliability of VANET communication. Communication in VANET is shown in Figure 1.

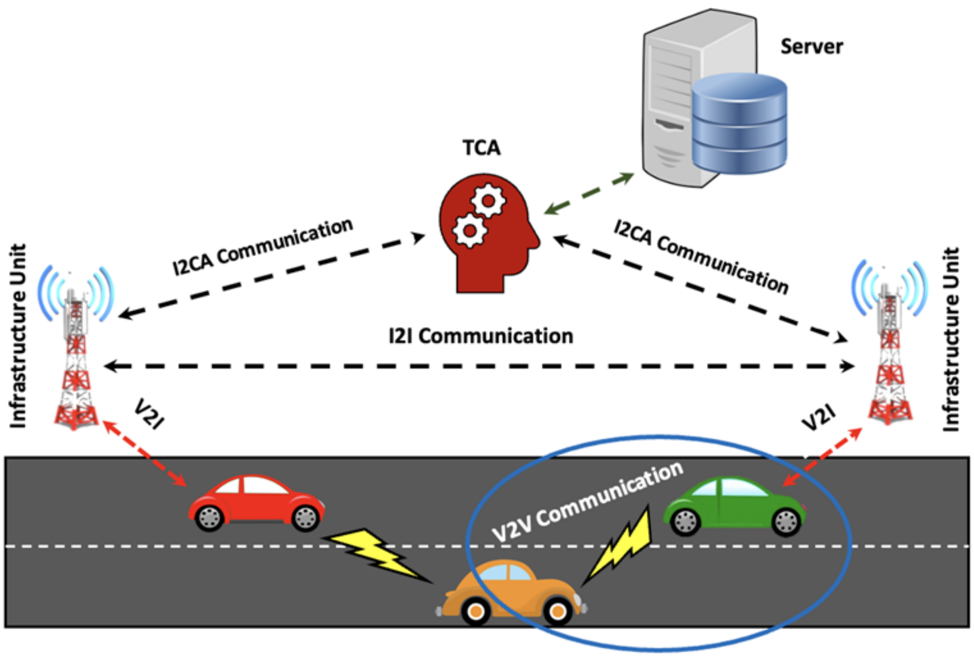

Figure 1 Communication in VANETs

Therefore, the fundamental issue which is encounter is that, in addition to other QoS characteristics, route discovery algorithms does not consider the duration of a communication link. This research provided a link-based technique to estimate the overall time available for this route. By assuming a connection failure before it happens and subsequently routing packets using a new channel, this methodology is designed to increase the quality of service. The links that are present among all route modules can be used to determine how readily available a route is. Therefore, it is critical to anticipate connection availability in order to determine the route's future availability.

The approximate time of an active link to adjacent nodes will be determined using “Newton divided difference interpolation”. When a connection failure between two nodes is likely based on this data, another path is constructed just prior to the link breakage happen. The packet experiences fewer drops as a result, shortening the recovery period.

1.1. Contributions

The key contribution of this proposed research is the design of a novel dynamic link prediction protocol for estimating the entire amount of time a route will be accessible based on QoS restrictions and creating a backup channel for data packets before the link is disconnected. The three key QoS metrics taken into account in this research are “delay, packet delivery ratio, and throughput”.

1.2. Organization

The next part of this paper is organized into the following sections: A discussion of literature review is provided in Section 2. Section 3 explains the specifics of the NDLP protocol and how it operates. Section 4 offers simulated scenarios and evaluates the outcomes of the simulation.

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Section 5 compares and contrasts the NDLP with the corresponding protocols. Section 6 concludes the Paper.

2. RELATED WORK

The dynamic nature of vehicular environments presents challenges in maintaining reliable and stable communication links between vehicles. Frequent link disconnections due to factors such as high vehicle mobility, obstacles, signal interference, and congestion can hinder the effectiveness of VANETs. To address this issue, researchers have proposed several link prediction protocols that aim to anticipate link stability and mitigate the impact of frequent link disconnections. In this literature review, the paper discusses the existing approaches and highlights the need for a novel dynamic link prediction protocol for VANETs.

J. Liu et al. have proposed a dead reckoning which is based on FD [1]. According to the others, through vehicle collaboration, it can properly estimate the movement of a vehicle and prevent the influence of “link failures” on the outcomes of detection. But it has strong overhead which decreases its efficiency in maintaining the link connection.

H. Ateeq et al. have presented a comparison of existing routing protocols for reliability [2]. The authors have described the need of improvement in the network parameters in terms of reliability. This can be further improved with the latest approaches in the design of routing protocols.

M. Harayama et al. have proposed GPSR, a routing protocol based on geographic data [3]. It uses this information for routing of data. The disadvantage of this approach is the enhancement of packet drop ratio.

V. Mehta et al. have proposed a model based on traffic prediction [4]. This model can be deployed in urban environment but it is not suited on highways. This problem can be addressed in the future research.

L. Yao et al. have proposed a vehicular centric based method to implement many technologies in content based network into VANETs [5]. Without depending on remote fetching, the network caching technique of content based network enables accessing and communication of the cached information across several nodes as an effective data access. However, significant improvement needs to be done on real time caching of information for the recovery of link disconnection.

S. A. Elsayed et al. have described a method based on assumption of proactive caching setup. It pre-caches the data present at stalled vehicles for the agents to proactively obtain as they proceed by taking advantage of the driving schedule and expected behaviour of users [6].

However, the caching mechanism requires more energy consumption which needs to be addressed.

An innovative pseudonym linking technique has been put up by R. Zhang et al. [7], with an emphasis on the prediction of acceleration and direction angle. In addition, the authors have incorporated a number of auxiliary data into the suggested method to enhance linking performance (e.g., road structure, traffic signal). This methodology performs well when there is limited count of vehicles but its behavior fall when the quantity of vehicles increases.

K. Koufos et al. have suggested an approach that calculates the moments of the meta distribution [8]. The drivers maintain wide safety gaps as a result of the high speeds, making the Poisson point process (PPP) an inadequate deployment model.

This method works well on roads with wide space but this technique is not suitable for the narrow roads.

The algorithm for link prediction has been put out by Naresh et al. which discusses about the breakage in the link during the communication process [9]. An expensive failure link connectivity requires many broadcast pauses to identify the issue, and then a new path needs to be constructed, delaying the re-establishment process. Given how seldom routes fail in wired network. The routing protocols that employ the described model have an impact on the QoS of the route despite the high frequency of path disconnections.

C. Zhang et al. have presented a routing protocol which will compute the next nodes when the previous case of forwarding is assumed to be invalid [10]. The advantage of this approach is link breakage identification but suffers with a drawback of link connectivity in real time.

H. Wang et al. have presented a method based on Kalman filter which is used to increase the speed of nodes [11]. The authors has deployed algorithms based on fuzzy logic to enhance the speed of nodes. However, the reliability can be further improved by integrating with the machine learning algorithms.

F. Lyu et al. have proposed a mechanism based on shared beacon congestion monitoring system to limit message activity while taking link status into account, whereby nodes with many neighbors and good connection with those neighbours will be given greater beacon rates [12]. In DBCC, the training of features is done using “naive Bayes and support vector machines”, two machine learning techniques, and then use the classifier model to perform online NLoS link condition prediction. The advantage of this method is high beacon transfer speed but at the same time suffers with the problem of high energy consumption

A new transmission mechanism based on spider web in automotive networks has been presented by T. Qiu et al. [13]. This mechanism establishes a spider web transmission model integrating geographic data systems and maps. The authors claim that TMED greatly reduces the delay of packets by combining a changing multipriority data queue management system with a constrained greedy forwarding method depending on location assumption but suffers with the problem of frequent link disconnections.

H. Ghafoor et al. have proposed a routing protocol based on SDN that computes a reliable route between the two adjacent nodes [14]. Since this is a routing protocol, location identifying is the main job of this protocol in order to increase stability of network by protecting the principal user action. This protocol cannot be implemented when the distance between the nodes increases.

M. Laroui et al. have proposed a routing protocol based on machine learning for predicting the direction of vehicles in urban environment [15]. This approach performs well in urban situation but its complexity increases on highway implementation.

An approach developed by M. Balfaqih et al. uses the IEEE 802.21 services and the HO-initiate process to improve the network-based handover process [16]. By conducting the HO-initiate procedure proactively, the authors have addressed the issue of binding registration delay. But this approach has a drawback of throughput overhead between sender and receiver nodes.

H. Yang et al. have presented a scheme depending on the position routing protocol [17]. Instead of only employing a greedy forwarding method, the basic algorithm of GPSR is implemented along with the link availability time (LAT) forecast. This maximizes the benefits of GPSR. The problem with this method is it will consume more time to find the availability of links in case of far nodes.

J. Zhang et al. have proposed link duration discovery method used to predict the duration of the links [18]. This method can be enhanced by implementing it with supervised machine learning techniques.

A deterministic method that offers a higher bound on the CRB ability with precise channel accuracy has been put forth by S. Bharati et al. [19]. Additionally, the authors provide a channel system on a Markov chain to choose the ideal node. The disadvantage of this method is the lack of prior information for the selection of ideal node for both the sender and receiver. In a system proposed by Ayubkhan et al., the strength of the signal received and path link time request are stored in the internal memory of each module, and the anticipated life time is modified periodically [20]. The destination module is once again modified after receiving the route response packet. Although there are many path disconnections in this design, the routing protocols that use it have an impact on the QoS of the route.

N. Alsharif et al. have presented a link prediction approach based on neural networks [21]. According to the authors, all the nodes are interconnected by using links to enable smooth communication. However, this approach can be implemented only on small set of nodes.

G. Zhioua et al. have proposed a coordinating traffic broadcast algorithm in VANETs [22]. This methodology works in establishing V2I communications but it is less effective in case of V2V communication. However, it has major overhead during the communication with distant devices.

S. Shelly et al. have proposed a link estimation scheme based on Kalman filter methodology [23]. It works well in the dynamic environment which involves a limited set of nodes but cannot be used effectively in large VANETs.

A. U. Khan et al. have presented a link identification approach based on time series data [24]. This method is preferred in case of sequential data in VANETs but considering the dynamic behavior of VANETs, it must be improved to suit this criteria.

A. Joshi et al. have designed a routing protocol based on multicasting approach to enable efficient link prediction [25]. The advantage of this method is prediction of links but the drawback is slow link discovery.

H. Gabteni et al. have proposed a method based on link state behavior to determine the link states [26]. The states of the link can be determined easily if the nodes are at small distance. If the nodes are far away from the network, then the state of the links cannot be determined easily.

A. O'Driscoll et al. have proposed a infrastructure based routing protocol which is used along with geographic information [27]. It is suitable for urban environment but lack properties to handle in highway situations.

G. Li et al. have designed an ant colony based optimization routing protocol [28]. This method selects the best route among multiple paths but at the same time creates an overhead in case of large scale VANETs.

P. Sahu et al. have designed a greedy based routing protocol for urban VANETs [29]. It is used for efficient routing of information in urban situation. Further, this can improved by integrating this approach with machine learning models.

E. D. N. Ndih et al. have proposed a prediction based scheme based on neighborhood nodes in VANETs [30]. According to the authors, the links of neighborhood nodes can be estimated easily. However, the far away nodes cannot be used with this scheme.

W. Viriyasitavat et al. have proposed a link prediction method for urban conditions [31]. This method can be applied for small set of nodes but can implemented in future for large set of nodes after improvement.

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M. Jerbi et al. have designed a routing protocol based on geographic information [32]. This information can be used to track the location of the nodes. However, use of active rfid scheme can be used for further improvement.

J. Zhao et al. have proposed a method based on vehicle assisted delivery of data in VANETs [33]. This ensures the smooth transfer of data among vehicles with less connectivity problems. However, it has major overhead in urban conditions. S. Kamali et al. have described a methodology based on ant colony optimization [34]. In this method, all the vehicle nodes can communication be using active link connection. Once, the connection breaks, this approach takes a lot of time to reestablish the connection between the links.

K. T. Feng et al. have proposed a medium access control protocol based on directional antennas [35]. The advantage of this method is the identification of nodes location. However, the location of vehicle nodes cannot be determined if they are at longer distances.

Naumov et al. have designed routing protocols based on intersection that are more reliable in urban VANETs. Because it stores full end-to-end routes, CAR make use of city digital maps to discover small routing patterns and is not suited to modifications in routing [36]. Network congestion may result from the concept that these stationary units are not connected by a unit and that continuous interactions modify the present delay across the two close-by intersections.

Table 1 Summary of Related Works

Author & Reference	Proposed Methodology	Advantages	Disadvantages
J. Liu et al. [1]	Dead reckoning based FD, called DR-FD	Vehicles movement estimation	Not efficient in maintaining link connection
H. Ateeq et al. [2]	Study of existing routing protocols	Reliable message broadcasting, link discovery and real time data exchange	Other network parameters may be considered
M. Harayama et al. [3]	A Routing methodology which is based on geographic data	Use of GPS based information for routing the data.	Increase in packet drop ratio
V. Mehta et al. [4]	Traffic prediction model	Suitable in urban situations	Not suitable in highways
L. Yao et al. [5]	A Vehicular centric approach to interconnect many vehicles	Exchanging and cooperation of cached data among vehicles	Frequent link disconnections
S. A. Elsayed et al. [6]	A Presumptive caching methodology for pre-caching of information	It pre-caches the data from vehicles	More energy consumption
R. Zhang et al. [7]	An innovative pseudonym linking technique	Used for prediction and acceleration of link performance	Not suitable for large set of vehicle nodes
K. Koufos et al. [8]	Approach that calculates the moments of the meta distribution	Suitable for wide space roads	Not suitable for narrow roads
Naresh et al. [9]	Path adjustments occur only when there's a broken connection along the existing route or when an alternative quick path is identified	Suitable for limited set of vehicle nodes	Frequent link disconnections
C. Zhang et al. [10]	A routing protocol to compute the next nodes in sequence	Link breakage identification	Not possible in real time
H. Wang et al. [11]	A Kalman filter based method to speed up the nodes	Nodes efficiency is increased	Uses fuzzy logic which cannot be used in real time
F. Lyu et al. [12]	Distributed Beacon Congestion Control (DBCC) mechanism	High beacon transfer speed	High energy consumption

T. Qiu et al. [13]	A mechanism for emergency transmission of data for measurement of network parameters.	Reduces delay of packets	Frequent link disconnections
H. Ghafoor et al. [14]	A Routing protocol based on SDN that determines a reliable path between sender and receiver	Location sensing for network stability	Not suitable when the distance between sender and receiver increases
M. Laroui et al. [15]	A routing protocol based on machine learning to detect direction of vehicles	Suitable in urban situation	Not suitable in highway conditions
M. Balfaqih et al. [16]	Network-based DMM's handover process	Solves the issue of binding registration delay	Throughput overhead
H. Yang et al. [17]	An enhanced method based on the position centric routing protocol.	Detection of links availability in case of link failure	Time consumption to detect availability of links
J. Zhang et al. [18]	A method to identify the duration of the links	Can be used for limited set of nodes	Not suitable for large number of nodes
S. Bharati et al. [19]	Higher bound on the CRB performance with precise channel data	Bidirectional channel for transmission of data	Lack of prior information to select ideal node
Ayubkhan et al. [20]	Link Prediction Routing Algorithm (LPRA)	Identification of links availability in case of broken links	Frequent path disconnections
N. Alsharif et al. [21]	A link prediction approach based on neural networks	Accurate link prediction for limited set of nodes	Not suitable for large number of nodes
G. Zhioua et al. [22]	A Mutual traffic broadcasting algorithm in interconnected VANETs	To establish V2I communication	Not suitable for V2V communication
S. Shelly et al. [23]	A link estimation scheme based on Kalman filter methodology	Link detection facility during communication	Link discovery is not accurate
A. U. Khan et al. [24]	A link identification approach based on time series data	Applicable only for sequential set of nodes	Not applicable for randomized collection of nodes
A. Joshi et al. [25]	A routing protocol based on multicasting approach	Accurate prediction of links	Link discovery is not possible
H. Gabteni et al. [26]	A method based on link state behavior to determine the link states	State of the links can be determined	Less accurate in case of longer distance nodes
A. O'Driscoll et al. [27]	A infrastructure based routing protocol which is used along with geographic information	Suitable in urban situation	Not suitable in highways
G. Li et al. [28]	A Routing protocol based on ant colony optimization technique	Best route selection among multiple paths	Not suitable for large scale VANETs
P. Sahu et al. [29]	A greedy based routing protocol	Efficient routing	Slow route discovery

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	for urban VANETs		
E. D. N. Ndih et al. [30]	A prediction based scheme based on neighborhood nodes	Neighborhood links can be estimate easily	Links of faraway nodes cannot be determined
W. Viriyasitavat et al. [31]	A link prediction method for urban conditions	Can be applied for small set of nodes	Not applicable for large set of nodes
M. Jerbi et al. [32]	A routing protocol based on geographic information	Nodes can be tracked by using location easily	Limited connectivity among the nodes
J. Zhao et al. [33]	A method based on vehicle assisted delivery of data in VANETs	Less connectivity problems	Major overhead in urban environment
S. Kamali et al. [34]	A methodology based on ant colony optimization	Active link connection	Time consumption for reconnection of the broken links
K. T. Feng et al. [35]	A medium access control protocol based on directional antennas	Identification of nodes location	Not suited if the nodes are at longer distances
Naumov et al. [36]	A Protocol based on intersection depending routing	Implements online maps to discover shortest path	Network congestion

The existing literature on link prediction in VANETs has made strides in improving link stability and mitigating the impact of frequent link disconnections. However, there is a need for a dynamic link prediction protocol that considers temporal aspects, underlying causes of link failures, and real-time observations to enhance prediction accuracy and adaptability. The proposed NDLP protocol aims to fill this gap by providing an innovative approach to tackle the challenges of frequent link disconnections in VANETs.

3. THE PROPOSED NDLP PROTOCOL

In this paper, a novel dynamic link prediction (NDLP) protocol is proposed. In general routing algorithms, a path change only takes place after a link along the route fails or when there is one shortest path. A connection failure is complex since it takes many broadcasting pauses to find the issue, and then a new route needs to be developed, which causes a latency in the redevelopment process. It is not a serious issue with wired network since routes break so infrequently. In any situation, in spite of the large count of link disconnections, “QoS of the route” is influenced by the protocols that implement the given model.

The proposed technique estimates the time at which the current link will fail. This is accomplished by determining the moment at which the signal intensity for packets drops below the designated cutoff energy. It is implied that the two modules move out of range of their respective transmission when the power strength received is less than the cutoff. With the use of the NDLP protocol, the sender can discover a new route before the path breaks due to the prediction of link break, which helps to provide route configuration while meeting QoS requirements.

3.1. Assumptions

For the “novel dynamic link prediction algorithm” to operate as intended, it is assumed that each vehicle consist of GPS feature, a navigation unit, and a digital map which provides information such as the speed of the vehicle, travel route, geographic location, intersection location, and length of the road segment. Additionally, it has been assumed that the various communication pairs have the same QoS needs and that the source nodes may access the geographic positions of the specific destinations via location services. In view of packet delivery ratio (PDR), delay, and connection lifespan”, NDLP seeks to identify the route with the best QoS in urban settings. The Architecture of Novel Dynamic Link Prediction (NDLP) Protocol is shown in Figure 2.

3.2. Best Route Selection

NDLP uses two units known as Terminal Intersection Source (TIS) and Terminal Intersection Destination (TID) to transmit data from sender to receiver. The flowchart for the process is shown below in Figure 3.

The direction of travel and the distance from nearby junctions are the two elements that determine a terminal intersection. The candidate with the highest score is picked as TIS based on the results, and TID is chosen using the same procedure. After choosing a “TIS”, it makes a path request in an attempt to use ants to identify the best possible path. Forward ants are the ones making this journey from TIS to TID. The path request data is promptly eliminated if the distance travelled by the ants is longer than the cutoff delay for that specific module. If the forward ant's travel time to the unit is shorter than the “cutoff delay”, it is chosen to return to “TIS” with the

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best route request data. Otherwise, it is turned back. Later on, these ants are referred to as backward ants. These returning ants bring a list of intersections with them that have been selected based on the QoS criteria. This procedure is repeated at each module, resulting in the creation of several ants, and the process proceeds as previously explained. These chosen backward ants return to the TIS by taking the same path they took to get there. Finally, the best route is selected from a variety of options based on the points assigned to each one. These ratings are given depending on the quality of the services. The "best route" is the one that satisfies QoS criteria and has the most significant score.

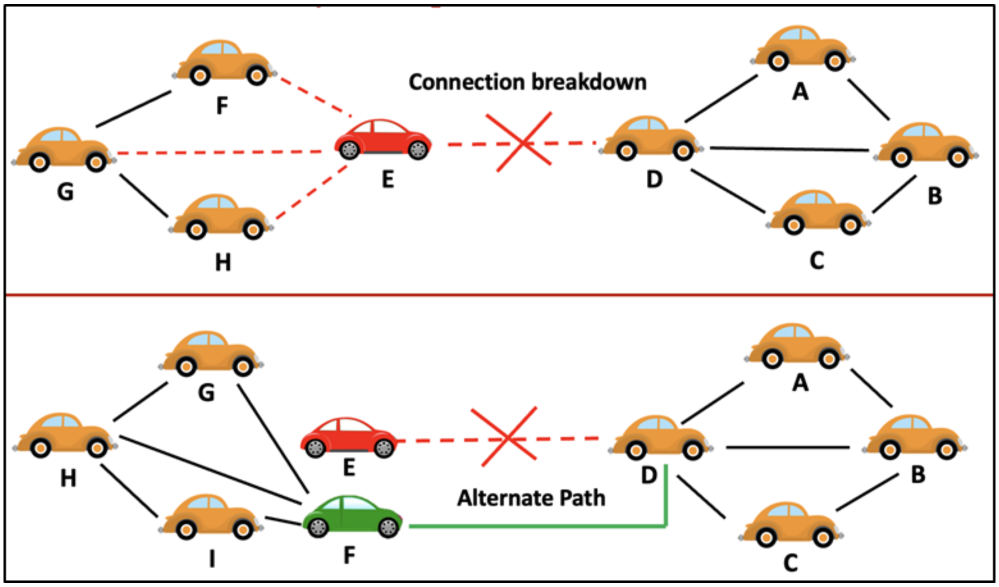

Figure 2 Architecture of Novel Dynamic Link Prediction (NDLP) Protocol

3.3. Link Prediction

By tracking the moment at which a module's power consumption drops below a threshold, link disconnection may be predicted. VANET modules move constantly therefore as they become farther apart and out of each nodes radio coverage. The connection failure is predicted using this process, which involves taking three back-to-back assessments of signal strength for packets received from the prior module. "Newton divided difference interpolation" can be used to calculate this connection failure.

Assume that "f(p0), f(p1), f(p2)…..f(pn)" be the n values of the function y=f(p) with respect to the inputs p=p0, p1, p2…pn, whose "interval differences" are not equal

The "first divided difference" is thus given in equation (1) as

$$f[p_0, p_1] = \frac{f(p_1) - f(p_0)}{p_1 - p_0} \quad (1)$$

The "second divided difference" is given in equation (2) as

$$f[p_0, p_1, p_2] = \frac{f[p_1, p_2] - f[p_0, p_1]}{p_2 - p_0} \quad (2)$$

and so on. Divided differences are independent of the argument order since they are similar with regard to the arguments as shown in equation (3). so, f[p0, p1]=f[p1, p0] f[p0, p1, p2]=f[p2, p1, p0]=f[p1, p2, p0]

$$f(p) = f(p_0) + (p - p_1) f[p_1, p_2] + (p - p_1)(p - p_2) f[p_1, p_2, p_3] + \cdots + (p - p_1)(p - p_2) \ldots (p - p_k) f[p_0, p_1, p_2 \ldots p_{k-1}] \quad (3)$$

The sum of the prediction time of all the expected broken links can be calculated by using equation (4)

$$(p + n - 1)^n = 1 + \frac{np}{2!} + \frac{n(n-2)p^2}{4!} + \cdots \quad (4)$$

The collected historical data points for link stability (shistory) at different time intervals (ti), where i = 1, 2, ..., n. The goal is to estimate link stability at a future time interval (tf).

(a) Data Preparation

The historical data points are

(t1, shistory1)

(t2, shistory2)

...

(tn, shistoryn)

(b) Calculate Divided Differences

Compute the divided differences for constructing the divided difference table:

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f[tx] = shistoryx

f[tx, ty] = (f[ty] - f[tx]) / (ty - tx)

f[tx, ty, tk] = (f[ty, tk] - f[tx, ty]) / (tk - tx)

...

(c) Construct Interpolation Polynomial

Construct the interpolation polynomial using the divided differences:

P(tf) = f[t1] + (tf - t1) * f[t2, t1] + (tf - t1) * (tf - t2) * f[t3, t2, t1] + ...

(d) Estimate Link Stability

Use the constructed interpolation polynomial to estimate link stability at the future time interval (tf):

sestimated = P(tf)

Critical time, as defined by the NDLP Protocol, is the amount of time needed to create a new route. This amount of time is enough for the source to discover a new path and to report an error to the next module. After some time, the module reaches a critical condition and must choose a new course. When a connection is likely to be lost, the source module tries to locate a path to the target. A broken link notification will be provided to the sender utilizing this link if no such route is located within the discovery period, which is a set amount of time. Alternative routes to the route discovery mechanism may be called by source modules. The power received at time t is sufficient to inform the upstream module and locate a different way, either by fixing the local route around the failing connection or by constructing an alternate path from sources. Links such as A, B, C, D, E, F, G, H, and I are restored locally in the specified number of hops as a result of received power reduction. Figure 4 illustrates how broken links in two hops, such as those between A and C and C and F, can be rebuilt. This approach to local route restoration seeks to reconstruct the damaged route locally with less overhead control for a rapid recovery. Every time a packet of data is received, the receiver module uses the dynamic link prediction method to analyze the link.

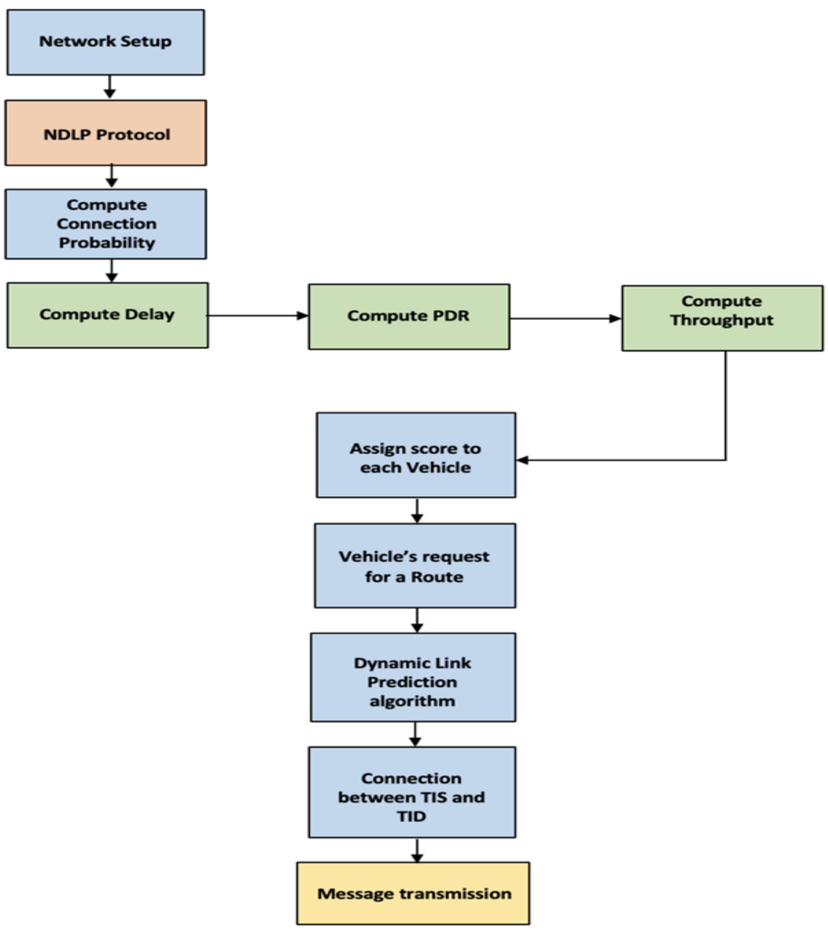

Figure 3 Steps for Selection of Best Route

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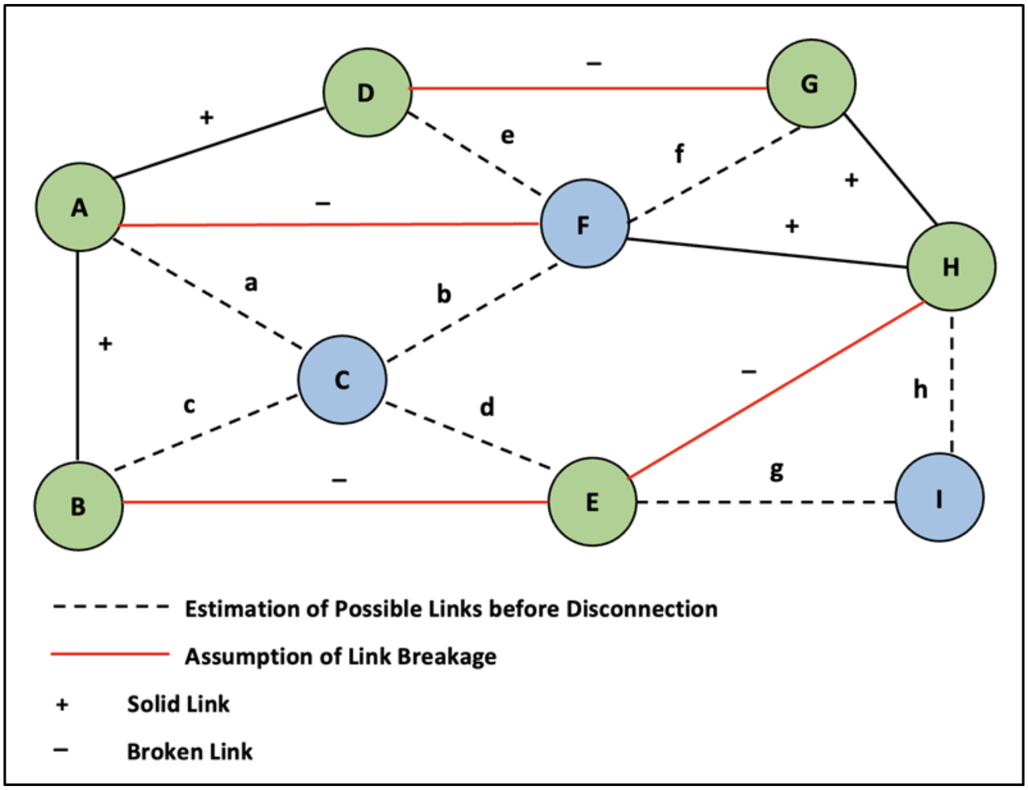

Figure 4 Working of NDLP Model

```
For each neighbouring node,
Upon receiving a packet,
If ((A>B) and (B>C)) in this case prediction();
prediction()
{
Estimate and update t1 and t, prior to link breakage
}
If (current time >= t)
{
Transmit notification to next module,
Update set time t
}
Upon accepting a message,
Set the path and link condition as strong,
Rebuild_Root ()
{
Determine path to next module i;
If (Determine path in j nodes in time)
Utilize this path for rerouting
Else
Determine path to Target D;
If (route found)
{
Transmit packet using next route,
Transmit new route discovery requests to senders
}
}
At Sender:
{
Determine new route after receiving a new route discovery alert
Forward traffic using new route
}
```

Algorithm 1 NDLP Protocol

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The algorithm 1 focuses on proactive routing and efficient utilization of network resources. It employs a prediction mechanism based on link conditions (A, B, C) to estimate and update timing parameters (t1, t). This enables the network to anticipate disruptions and optimize packet transmission accordingly. Additionally, it highlights the importance of timely notifications and route adjustments to minimize idle intervals between service and control channels, enhancing overall network responsiveness.
The concept of rebuilding the root and path determination underscores adaptability, allowing the network to dynamically select optimal routes and respond to changing conditions. Furthermore, the sender's role in route determination and traffic forwarding showcases a decentralized approach to routing decisions, promoting efficiency and adaptability in data transmission.

4. SIMULATION RESULTS

The performance measurements are used to evaluate the value of a routing protocol on both a qualitative and quantitative level. The implemented performance metrics are as follows:

4.1. Simulation Parameters

In the simulation tests, the network is mimic using Network Simulator Version 3.38. The simulation area is 1000 metres by 1000 metres, with 10 vehicles moving at a maximum speed of 60 metres per second (m/s). Constant Bit Rate (CBR) is applied to create traffic movement. Each module's coverage is 250 metres, and the simulation lasts 15 seconds. The data from chosen sender and receiver modules are routed using the NDLP protocol. In Table 2, the remaining simulation setup is presented.

Table 2 Simulation Parameters

Parameter	Value
MAC Protocol	IEEE 802.11p
Traffic Mechanism	CBR
Transmission Coverage	250 m
Transmission Speed	1KB/0.1ms
Size of Packet	1 KB
Modules	10
Simulation Duration	15 Seconds
Routing Protocol	NDLP
Channel Bandwidth	10 Mbps
Highest Speed	60 m/s
Area	1000 m x 1000 m

4.2. Delay

Delay is the difference between the times at which a packet is created by the sender and received by the recipient. Awk content is used to compute delay and produce the resulting document and output.

The obtained results of NDLP and its comparative protocols in terms of delay (in ms) is shown in Table 3.

The packets from point to point are determined by this metric value.

Delay = $PtR - PtS$

Where,

PtR = Received Packet Time

PtS = Sent Packet Time

dee = L[dtt+dpgt+dpct+dqt]

dee = node-to-node delay

dtt = delay in transmission

dpgt = delay in propagation

dpct = delay in processing

dqt= delay in queuing

L= count of links (count of routers - 1)

All the routers have their own dtt, dpgt, dpct.

However, this formula provides a preliminary approximation.

Figure 5 shows reduction in delay in NDLP compare with its counterpart protocols.

Table 3 Delay Performance in Various Scenarios

Scenario	NDLP	LPA	AQRV
1	0	0	0
2	0.2	0.4	0.5
3	0.5	0.8	1
4	0.7	1.4	1.6
5	0.8	1.7	1.8
6	0.9	1.3	1.5
7	1	1.1	0.9
8	0.8	0.9	1
9	0.7	1.2	1.1
10	0.7	1	0.9
Average	0.63 ms	0.98 ms	1.03 ms

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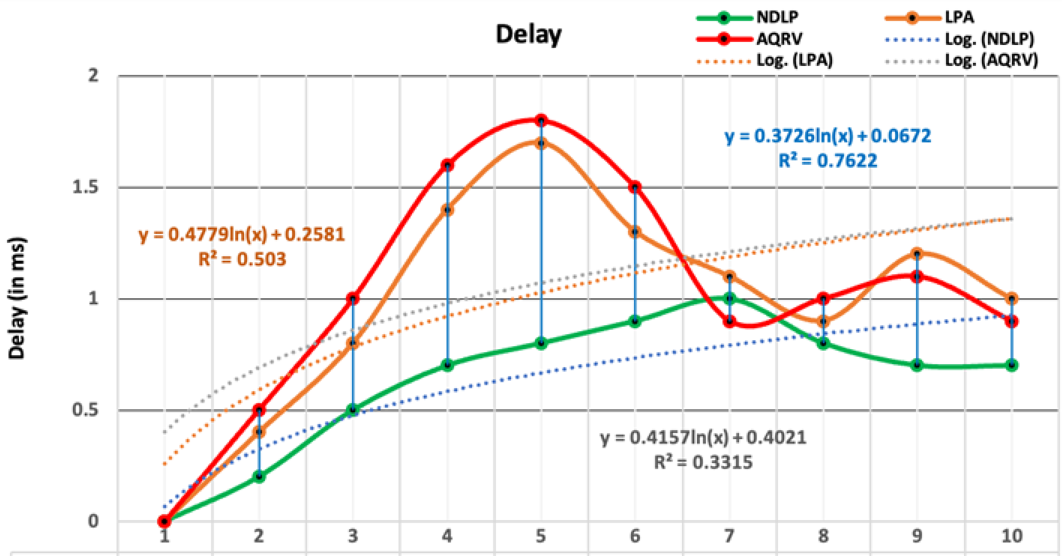

	1	2	3	4	5	6	7	8	9	10
NDLP	0	0.2	0.5	0.7	0.8	0.9	1	0.8	0.7	0.7
LPA	0	0.4	0.8	1.4	1.7	1.3	1.1	0.9	1.2	1
AQRV	0	0.5	1	1.6	1.8	1.5	0.9	1	1.1	0.9

Figure 5 Delay Performance of NDLP and Comparative Protocols

4.3. Packet Delivery Ratio

Table 4 PDR Performance in Various Scenarios

Scenario	NDLP	LPA	AQRV
1	0	0	0
2	1.3	1.1	0.5
3	1.3	1.2	1
4	1.5	1.4	1.3
5	1.4	1.5	1.4
6	1.6	1.4	1.3
7	1.6	1.1	1.1
8	1.5	1	1.2
9	1.7	1	1.1
10	1.7	1.4	1.4
Average	1.36 ms	1.11 ms	1.07 ms

It is the ratio of properly sent packets to a receiver over the total count of packets sent by the sender. Depending on the packets which are created and received that are logged in the trace file, the packet delivery ratio is computed. NS 3.38 produced trace file is processed by an awk script to obtain the result depicted in figure 6.

The obtained results of NDLP and its comparative protocols in terms of PDR (in ms) is shown in Table 4.

$$PDR = \frac{No.\ of\ packets\ received}{Total\ No.\ of\ packets\ sent}$$

4.4. Throughput

Data rates sent to all network terminals are added together to get the aggregate throughput.

$$Throughput = \frac{\sum PR}{\sum t_{st} - \sum t_{sp}}$$

Where, PR = Size of the Packet received, tst = Begin Time, tsp = End Time, Unit – bps

Throughput in the concept of dynamic link prediction in VANETs typically refers to the rate at which the prediction system can accurately forecast the future links or connectivity between vehicles. This involves estimating how well the prediction algorithm performs in terms of predicting whether a link between two vehicles will exist in the near future.

Here are some key performance metrics used to evaluate the throughput or accuracy of dynamic link prediction in VANETs:

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- True Positive (TP): No. of actual links that were properly assumed to exist.
- True Negative (TN): No. of nonexistent links that were properly assumed not to exist.
- False Positive (FP): No. of nonexistent links that were improperly assumed to exist (false alarms).
- False Negative (FN): No. of actual links that were improperly assumed not to exist (missed detections).

The obtained results of NDLP and its comparative protocols in terms of throughput (in bps) is shown in Table 5. Figure 7 shows an enhancement in throughput when NDLP is used.

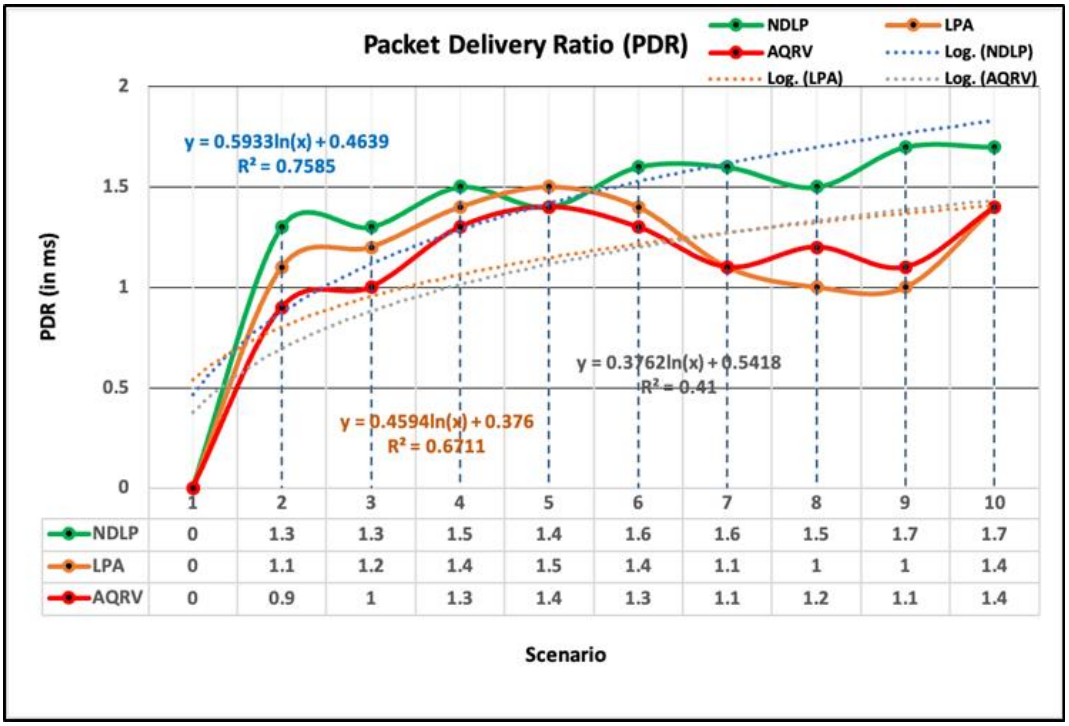

Figure 6 PDR Performance of NDLP and Comparative Protocols

Table 5 Throughput Performance in Various Scenarios

Scenario	NDLP	LPA	AQRV
1	0	0	0
2	52	45	35
3	58	52	47
4	65	61	44
5	70	65	48
6	71	64	54
7	74	63	53
8	72	65	52
9	70	50	58
10	77	54	50
Average	60.9 bps	51.9 bps	44.1 bps

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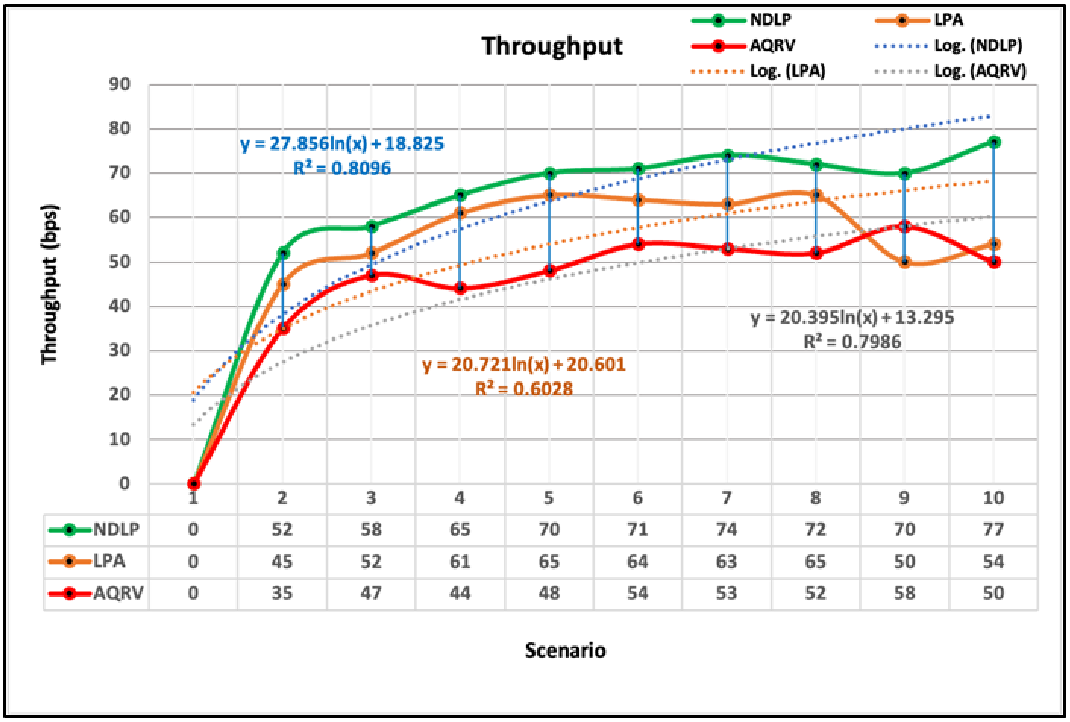

Figure 7 Throughput Analysis of NDLP and Comparative Protocols

5. SYNTHESIS

Table 6 Comparison and Synthesis of NDLP with its Counterpart Protocols

Routing Scheme	Delay	Packet Delivery Ratio (PDR)	Throughput
NDLP	0.63 ms	1.36 ms	60.9 bps
	Low	High	High
LPA	0.98 ms	1.11 ms	51.9 bps
	Medium	Medium	Medium
AQRV	1.03 ms	1.07 ms	44.1 bps
	High	Medium	Medium

As shown in the Figure 5, the NDLP protocol exhibits a significantly less delay in comparison with its counterpart protocols which is represented as Low in the Table 6.

The packet delivery ratio of NDLP as shown in Figure 6 is much better in comparison with its counterpart protocols and hence it is represented as High in Table 6.

As shown in the Figure 7, the NDLP protocol achieves a high throughput in comparison with its counterpart protocols which is represented as High in the Table 6.

The performance of the proposed model is significantly improved compared with the existing approaches due to the use of newtons interpolation formula by proactively anticipating link disconnections and dynamically rerouting data packets through alternative paths.

Hence, it can be observed from the above analysis that the proposed NDLP protocol performs efficiently than both the “LPA and AQRV protocols” in case of delay, PDR and throughput.

6. CONCLUSION

This paper presented a significant advancement in addressing the persistent challenge of frequent link disconnections in Vehicular Ad hoc Networks. The proposed novel dynamic link prediction protocol (NDLP) offers a promising solution to enhance the network's reliability and Quality of Service (QoS) by predicting and mitigating link failures. Through the utilization of Newton's divided difference interpolation, the protocol effectively evaluates the availability of active links to neighboring modules, enabling timely predictions of impending connection breakdowns. By proactively anticipating link disconnections and dynamically rerouting data packets through alternative paths, the protocol establishes a foundation for more resilient communication within VANETs. Furthermore, the positive results demonstrated through simulations validate the efficiency of the NDLP approach in minimizing disruptions caused by link failures in view of “delay, packet delivery ratio and throughput”. The protocol's ability to predict link unavailability and promptly adapt routing strategies showcases its potential to

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revolutionize the way VANETs manage communication in dynamic and challenging environment.

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