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Improvising QoS through Cross-Layer Optimization in MANETs

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Abstract: In Mobile Adhoc Networks (MANETs), nodes are mobile and interact through wireless links. Mobility is a significant advantage of MANETs. However, due to the unpredictable nature of mobility, the link may fail frequently, degrading the Quality of Service (QoS) of MANETs applications. This paper outlines a novel Ad hoc On-Demand Distance Vector with Proactive Alternate Route Discovery (AODV-PARD) routing protocol that uses signal strength-based link failure time estimation. The node predicts the link failure time and warns the upstream node through a warning message about the failure. On the basis of this information, a mechanism for identifying alternate routes is started in order to reroute traffic to the alternate route prior to the link failure. It significantly reduces packet loss and improves all the QoS parameters. The suggested protocol is compared to the traditional Ad hoc On-Demand Distance Vector (AODV) routing protocol and shows that the outlined protocol results in an improvement in QoS.

Index Terms: MANET, Link Failure, AODV, Cross-Layer Design.

1. Introduction

MANET [1] is comprised of wireless mobile nodes that interact together to establish an infrastructure-less network. Such networks offer distinct characteristics such as low-cost infrastructure, self-organization and mobility. Routing is required in MANETs due to the fact that mobile nodes can interact through a single hop or multiple hops. Between source and destination, a routing protocol can be used to build an optimal as well as loop-free route.

Routing protocols can be broadly classified as reactive, proactive, or hybrid [2]. When data transmission is required, reactive routing protocols such as AODV [3], initiate the route search process. Proactive routing protocols such as Destination Sequenced Distance Vector (DSDV) [4], keep a record of routing information before the start of data transmission. Hybrid protocols, such as the Zone Routing Protocol (ZRP) [5], combine the advantages of reactive and proactive routing protocols.

Due to its inherent flexibility and ease of implementation, MANET utilisation has been growing at an exponential rate in a wide range of applications [6], including military communications, Internet of Things (IoT), disaster relief etc. Real-time applications such as IoT have a low tolerance for network failures. As a result, determinism in performance is required for these applications. To meet growing expectations for guaranteed performance, communication technology has transformed from best-effort service to service assurances in terms of QoS [7]. The QoS aims to shape network characteristics in order to attain deterministic performance, allowing users to benefit from demanding services that meet their application's requirements. Performance can be quantified using a variety of metrics, including packet delivery ratio, throughput, control overhead, delay and so on, depending on the application. QoS is affected by various factors such as link failure due to frequent topology changes, limited battery capacity, the wireless channel's time-varying characteristics etc.

The availability of links between mobile nodes is determined by factors such as mobility, channel fading, shadowing and energy consumption. The objective of this paper is to analyse the mobility of nodes, as it is the leading cause of link failure. This paper outlines the AODV-PARD routing protocol, which improves QoS by predicting link failure and rerouting data packets over an alternate path to prevent packet loss due to link failure. The Least-Square Quadratic Polynomial Regression-based-Link Failure Time Estimation (LSQPR-LFE) technique [8] is utilised to estimate the link failure time, as described in our earlier work.

The paper's structure is as follows: Section 2 reviews the existing literature in this area. In Section 3, we describe a novel AODV-PARD routing protocol for improving the QoS of the network. In Section 4, we will investigate the performance of the AODV-PARD routing protocol. The concluding part contains some observations.

2. Literature Survey

In [9], the authors discussed a concise model for calculating link as well as route stability using received signal strengths. By including few other additional fields in route request and reply packets, route stability information can be used to select the more stable route possible between a given source and destination pair. Additionally, the incorporation of a signal strength-based admission control improves the routing's performance. The proposed routing reduces the total number of route recoveries needed during QoS data transmission by incorporating an easy route stability model. In [10], the authors described a novel routing protocol which considers unpredictable topology changes as well as frequent link failures. Meanwhile, the proposed approach is capable of accurately predicting link availability in a short period using a rough estimate of the distance within two neighbouring nodes.

In [11], the authors proposed a mechanism for avoiding route breaks based on signal strengths. This proposed scheme is being used to estimate link failures. The routing scheme takes the signal strength into account when constructing the route and then uses it to predict the route periodically. In [12], the authors introduced a new algorithm based on cross layer design for reducing link breakage in MANETs. The authors discussed three schemes for reducing packet retransmissions by transferring signal information within the physical and mac layers, as well as how to avoid frequent route failures in MANETs by identifying soon-to-be-broken links rather than predicting received signal power. To determine the optimal route maintenance by taking bandwidth and delay into account increases QoS.

In [13], the authors introduced a method for predicting link availability based on signal strength for use in AODV routing. The nodes estimate the time required for a link to break and further notify the other nodes about the route's link breaks. This information is used to initiate either local route repair or new route discovery much earlier than the route failure occurs. In [14], the authors proposed an algorithm that utilises the received signal strength and the rate at which the received signal strength changes to forecast the link available time after which an activation link will fail. The nodes overestimate the time required for the link to fail and discover an alternate route to the destination much earlier. In [15], the authoes proposed a novel routing approach for Mobile Adhoc Networks (MANETs) that would determine the most reliable and optimal routing paths between transmitter and the receiver in a MANET. In [16], the authors outlined AODV routing strategy with an enhanced maintenance phase, to improve QoS. It estimates link failure in use based on signal strength, allowing us to determine whether the link's quality will improve (i.e. remain stable) or degrade (i.e. probability of failure), allowing us to not only improve link management's robustness but also anticipate link failure as well as improve QoS.

In [17], the authors proposed a cross-layer approach for power control as well as link prediction. A cross-layer interaction parameter, the packets' received signal strength has been utilized, which offers a combined solution for power conservation and link availability. This uses a cross-layer approach to combine the effects of optimum transmit power and link availability estimation with the AODV. To extend the battery life of Adhoc nodes and improve the received signal, this method proposes to use optimised transmit power for transmitting packets to the next nearest node. In [18], the authors offered a new routing algorithmto achieve highly reliable transmissions of data. The recommended Routing Algorithm is an upgrade of the original Dynamic source routing protocol (DSR). During the route discovery phase, routes are selected based on the signal strength of received route reply (RREP) packets between intermediate nodes. In [19], the authors outlined routing mechanism for regulating route request flooding and predicting link failure to avoid the link failure due to mobility of node.

3. Cross-layer Design

Due to the dynamic nature, unpredictable channel conditions and limited resource availability of wireless adhoc networks, the conventional approach of optimization at different layers is insufficient. To achieve the better outcomes, optimizations must be performed using information available across several layers. Cross-layer design [20] is a concept in which the non-adjacent layers interchange the information for improving the overall performance of the network. As depicted in Fig. 1, the physical layer and network layer interact in the proposed work to predict link failure and provide an alternate path. The Received Signal Strength Indication (RSSI) is the critical parameter at the physical layer, and it is passed to the network layer for estimating the link failure time and determining an alternate path for data transmission prior to link failure.

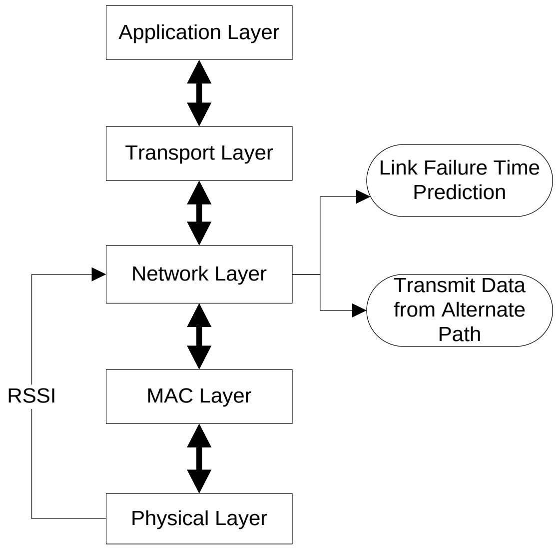


Fig.1. Cross-layer interaction between physical layer and network layer

4. Proposed Work

In this section AODV-PARD routing protocol is outlined which is based on traditional AODV routing protocol [3] but with novel local route repair procedure. When a link fails during data transmission, traditional AODV routing protocol either repair the route locally or initiate a new route discovery procedure, which results in packet drops and reduces the network's performance. If the link failure time is known in advance, the routing protocol can discover an alternate path before link failure. By redirecting the data packets through alternate path to avoid link failure this significantly increases the QoS.

4.1. Link Failure Time Estimation

In our previous work, LSQPR-LFE technique [8] is discussed for estimating when an active link fails. The time at which the RSSI of the data packets falls below a predetermined threshold power level is estimated using this technique. RSSI is less than the threshold value, indicating that the two nodes are moving out of the radio transmission range of one other.

Successive RSSI measurements of data packets received from the predecessor node *(i)* at node *j* are used to estimate the link failure time. Node *j* keeps the track of the most recent distances (Ds_{i,j_1}, $Ds_{i,j_2}, \dots Ds_{i,j_p}, \dots, Ds_{i,j_n}$) calculated by RSSI of data packets using Friis formula [21] and their arrival time (Tm_{i,j_1}, $Tm_{i,j_2}, \dots Tm_{i,j_p}, \dots, Tm_{i,j_n}$) for each transmitter from which it receives. It is assumed when RSSI of data packets is below at_{th} which is a predefined antenna threshold [22] given by the designer, then there is a chance that the link will fail in future. Therefore link failure time prediction procedure is invoked. The distance between nodes is treated as a variable in this approach, depending on the time of packet arrival. Equation 1 presents a linear system of equations for least square regression-based quadratic polynomial fitting [23].

$$\begin{bmatrix} n & \sum_{p=1}^{n} Tm_{i,j_p} & \sum_{p=1}^{n} {Tm_{i,j_p}}^2 \\ \sum_{p=1}^{n} Tm_{i,j_p} & \sum_{p=1}^{n} {Tm_{i,j_p}}^2 & \sum_{p=1}^{n} {Tm_{i,j_p}}^3 \\ \sum_{p=1}^{n} {Tm_{i,j_p}}^2 & \sum_{p=1}^{n} {Tm_{i,j_p}}^3 & \sum_{p=1}^{n} {Tm_{i,j_p}}^4 \end{bmatrix} \times \begin{bmatrix} h_{i,j} \\ j_{i,j} \\ k_{i,j} \end{bmatrix} = \begin{bmatrix} \sum_{p=1}^{n} Ds_{i,j_p} \\ \sum_{p=1}^{n} Ds_{i,j_p} Tm_{i,j_p} \\ \sum_{p=1}^{n} Ds_{i,j_p} {Tm_{i,j_p}}^2 \end{bmatrix} \quad (1)$$

Ds_{i,j_p} specifies the distance between nodes *i* and *j* at a specific packet arrival time Tm_{i,j_p} for each pth packet. The coefficients of a quadratic polynomial are $h_{i,j}$, $j_{i,j}$ and $k_{i,j}$ .Using the Friis transmission formula, the Ds_{th} between transmitter and receiver can be derived from the at_{th}. At the time of link failure, this Ds_{th} lies on quadratic polynomial. It can be stated mathematically as follows.

$$Ds_{th} = h_{i,j} Tm^2 + j_{i,j} Tm + k_{i,j} \quad (2)$$

Sridharacharya formulae [24] can be used to determine the link failure time ($Tm_{i,j_{failure}}$).

$$Tm_{i,j_{failure}} = \frac{-j_{i,j} \pm \sqrt{{j_{i,j}}^2 - 4h_{i,j}k_{i,j}}}{2h_{i,j}} \quad (3)$$

4.2. Proactive Alternate Route Discovery(PARD)

Once link failure is accurately predicted using the proposed LSQPR-LFE, various mitigation measures must be taken to avoid the link in order to avoid the damages that link failure may cause, such as packet loss, delay and new route discovery procedures. This paper shows a proactive way to find an alternative path ahead of time so that the predicted link failure doesn't happen and the current packet transmission doesn't change. If an alternate path exists, the packets are diverted to a new path to avoid link failure.

In a specific scenario, as shown in Fig. 2, Source node S has packets to be transmitted to Destination node D. There is a node Y in the route, which receives packets from node X and forward it to Z. Y is responsible for predicting the link failure time ($Tm_{x,y_{failure}}$) of X-Y link. Y initiates PARD procedure if it finds that the link is about to fail by comparing the critical time threshold ($Tm_{x,y_{cs}}$) with $Tm_{x,y_{failure}}$ and sends a message that contains the address of the next-hop (Z) to the upstream node (X). X is now responsible to initiate a common _neighbour _discovery procedure to find a common neighbour between X and Z (say N). X uses another soon-to-broken time threshold ($Tm_{x,y_{broken}}$) to bypass the X-Y link by forwarding packets from X-N-Z.

AODV-PARD routing protocol transmitted five messages in order to find an alternate path through a common neighbour: a Warning (WAR) message, a Common Neighbour (CMNB) message, a Common Neighbour Reply (CMNB R) message, a New Routing (NR) message and an Update Routing (UR) message.Their respective structures are depicted in Table 1, Table 2, Table 3, Table 4 and Table 5.

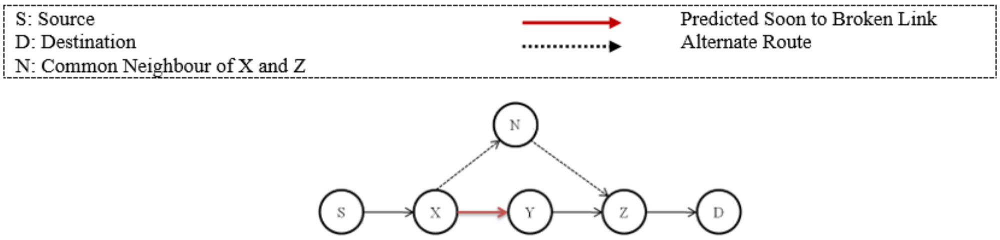


Fig.2. AODV-PARD routing protocol

Table 1. WAR message format

Onehop_Nexthop (1hp_Nxthp)	Originator_Address (O_Addr)	Destination_Address (D_Addr)

Table 2. CMNB message format

Destination_Address (D_Addr)	Originator_Address (O_Addr)	Second_Nexthop (S_Nxthp)	Active_Destination Sequence(A_DSNo.)

Table 3. CMNB_R message format

In_Route	Originator_Address (O_Addr)	Destination_Address (D_Addr)

Table 4. NR message format

Destination_Address (D_Addr)	Destination_Sequence Number (D_Sno.)	Hop_Count (H_Cnt)	Next_Hop (N_Hp)	Expiry_Time (E_Tm)

Table 5. UR message format

Destination_Address (D_Addr)	Next_Hop (N_Hp)

4.3. Algorithms

This section gives the algorithams for LSQPR-LFE technique and finding an alternate path to avoid the predicted link failure outlined in the preceding Section 4.1 and Section 4.2 respectively.

Algorithm 1: LSQPR-LFE Technique Description: To predict link failure time on receiving data packets	
At receiver node –Y	
1	Receives data packets from X (As shown in **Fig. 2**)
2	Maintains a record of the last five data packets as (Distance calculated by RSSI (Ds_{x,y_n}), Arrival time).
3	If($Ds_{x,y_1} < Ds_{x,y_2} < Ds_{x,y_3} < Ds_{x,y_4} < Ds_{x,y_5}$)
4	{
5	Link_Failure_Time_Prediction()
6	Predict and update $Tm_{x,y_{failure}}$, which is the estimated time, when the link will fail
7	}

Algorithm 2: PARD Description: To find the alternate path based on predicted link failure time	
At receiver node –Y	
//Y sends warning messageto upstream node X about link failure	
1	If($Tm_{x,y_{failure}}$ - Current_Time =<$Tm_{x,y_{cs}}$)
2	{
3	Y fetches address of X from received Data Packets and address of Z is fetched from next-hop entry of its routing table (rt) and generates a unicast WAR message with following fields: WAR→1hp_Nxthp = rt→next-hop (Z) WAR→O_Addr = Y WAR→ D_Addr =X Y forwards WAR message to X
4	}
At sender node –X	
//On receiving WAR message Common_Neighbour_Discovery() procedure is invoked and X waits for response	
5	Receive_WAR()
	{
	Common_Neighbour_Discovery()
	X waits for response
	}
	// *X receives CMNB_R message form common neighbor node-N*
6	Receive_CMNB_R ()
7	{
8	If(CMNB_R→in_Route==-1)*// N is not in the active route*
9	{
// For creating a new routing entry at N for D with next-hop is Z	
10	NR message is generated with all routing entries of X for a particular destination sequence number of D except next hop NR→D_Addr = rt→destination_address NR→D_Sno = rt→destination_sequence_number NR→H_Cnt = rt→hop_count NR→N_Hp = Z NR→E_Tm = rt→expiry_time X forwards NR message to N
11	}
12	Else if(CMNB_R→in_Route==1) // *N is in the active route*
13	{
// For updating routing table entry of N for D with next-hop Z	
14	UR message is generated with following field UR→next _hop = WAR→1hp_Nxthp (Z) X forwards UR message to N(common neighbour of X and Z)
15	}
// X has to divert the data packets through discovered alternate path between X and Z	
16	If($Tm_{x,y_{failure}}$ - Current_Time =<$Tm_{x,y_{broken}}$)
17	{
18	Routing table of X is updated by: rt→next_hop= CMNB_R→ O_Addr (N)
19	Redirect the traffic through new path(X-N-Z)
20	}
21	}

Algorithm 3: Common Neighbour Discovery Algorithm Description: To find the common neighbour between X and Z	
Common_Neighbour_Discovery()	
At sender node –X	
1	X generates CMNB message with following fields: CMNB→D_Addr = 255.255.255.255 CMNB→O_Addr = X CMNB→ S_Nxthp = WAR→1hp_Nxthp (Z) CMNB→ A_DSNo. = rt→destination_sequenceno X broadcasts CMNB to the neighbour nodes of X
At neighbours node –N	
// All neighbours of X will receive CMNB message and check its neighbour table for entry of Z	
2	Receive_CMNB_R ()
3	{
4	If(Z is found in the neighbour list)
5	{
6	If (CMNB→active_destination_sequence!= rt→destination_sequenceno) // *Node is not in the current active route*
7	{
8	N generates the CMNB_R message with the following field: CMNB_R→O_Addr = N CMNB_R→D_Addr = X CMNB_R→in_Route=-1 N forwards CMNB_R message to X
9	}
10	Else *//Node is in the current active route*
11	{
12	N generates the CMNB_R message and send to node Xwith the following field: CMNB_R→O_Addr = N CMNB_R→D_Addr = X CMNB_R→in_Route=1 N forwards CMNB_R message to X
13	}
14	}
15	Else
16	{
17	Drop the CMNB message
18	}
19	}

5. Findings and Discussion

Simulating real-world scenarios is the most efficient and cost-effective way to evaluate their performance. NS2.35 [25] is the major tool used to configure a MANET system and to determine the performance gain of AODV-PARD over AODV.

5.1. Assumptions

To establish an appropriate simulation environment for MANET, the following hypotheses must be made:

- Each link must be symmetrical as well as bidirectional.
- There is no consideration for interference.
- Each node is having fixed as well as similar range of communication.
- The network size remains constant during the simulation.

5.2. Environment Setting

Certain parameters must be predefined prior to the start of the simulation, while others are case-dependent. Random Waypoint mobility model is used. The simulation is performed on a network area of *3000m×3000m* with a number of mobile nodes ranging from *25 to 100*, pause time varying from *20 to 100 seconds* and velocity of nodes ranging from *4 to 20 meters/second*. Mobile nodes are assumed to have a communication range of *250 meters*. This means that only one hop communication link between two mobile nodes can be established if their distance is less than or equal to *250 meters*. To simulate a realistic MANET environment, the simulation settings provided in Table 6 have been used.

Table 6. Simulation parameters

Parameters	Values
Area	3000 m × 3000 m
MAC protocol	IEEE 802.11
Velocity	5, 10, 15, 20 m/s
Simulation Time	1000 s
Number of nodes	25, 50, 75, 100
Pause Time	20, 40, 60, 80, 100 s
Propagation type	Two Ray Ground
Initial Energy	60 J
Application Agent	CBR
Packet size	512 bytes
Mobility Model	Random Waypoint Model
Antenna type	Omni Directional Antenna
Communication Range	250m
Sent Packets	6000

The various parameters used to assess performance are mentioned below.

- *Link Failure Count:* The total number of active link failure during data transmission.
- *Control Overhead:* The total number of routing packets sent over the network.
- *Normalized Routing Overhead:* The total number of routing packets transmitted per data packet.
- *End-to-End Delay:* The time required for a data packet to be transferred from source to destination over a wireless ad hoc network.
- *Number of Received Packet:* The total number of received packets at destination.
- *Packet Delivery Ratio:* The proportion of data packets received by the destination to data packets transmitted by the source.
- *Throughput:* The average number of successfully transmitted data packets per unit time, expressed in bits per node per second.

Routing simulations were conducted with varied network topologies and the performance parameters were averaged to determine the proposed AODV-PARD routing protocol's efficiency. The Gnuplot application [26] is used to visualize the proposed AODV-PARD routing protocol's performance.

5.3. Result Analysis

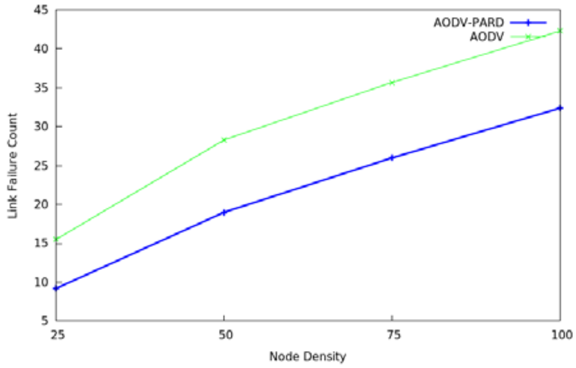
In this section, the performance of AODV-PARD routing protocol is analyzed and compared with traditional AODV routing protocol.

A. Based on Node Density

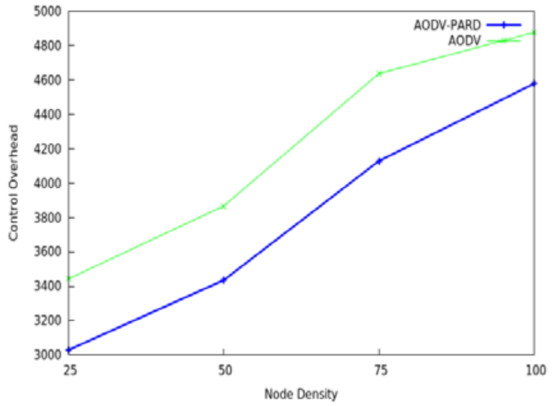
The simulation results for the AODV and AODV-PARD routing protocols are obtained when the network size is varied in order to determine the influence of node scalability on the routing protocols. To obtain the findings shown in Fig.3(a) to Fig.3(g) the size of network is varied while the other simulation parameters are assumed to be constant, with a pause time of *90 seconds* and the velocity of *5 meters/second*.

In Fig.3(a) the result indicates that AODV-PARD has significantly less link failure count than AODV. This happens because, in AODV-PARD alternate routes are found well in advance of a link failure and data packets are delivered via an alternative route. Additionally, as node density increases, the link failure count increases. The reason behind this is the availability of several routes in the topology which leads to purposefully switch over to the optimal routes and this leads to an increase in link failure.

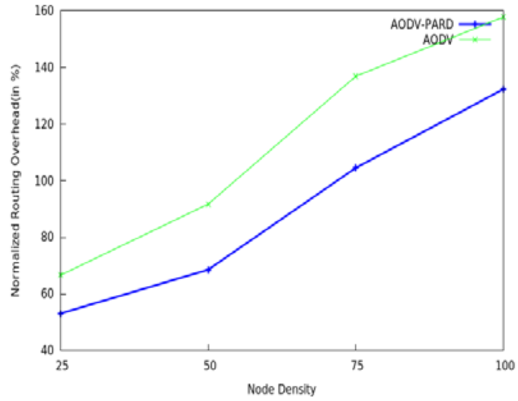
Fig.3(b), Fig.3(c) and Fig.3(d) demonstrate that control overhead, normalized routing overhead and delay are significantly lower in AODV-PARD than in AODV, while Fig.3(e), Fig.3(f) and Fig.3(g) represent that the number of received packets, packet delivery ratio and throughput are higher in AODV-PARD than in AODV. Furthermore, AODV-PARD and AODV both have a larger control overhead, normalized routing overhead and delay; have a lesser number of received packets, packet delivery ratio and throughput with an increase in node density. This is because link failure count is directly proportional to control overhead, normalized routing overhead and delay; it is indirectly proportional to the number of the received packet, packet delivery ratio and throughput.



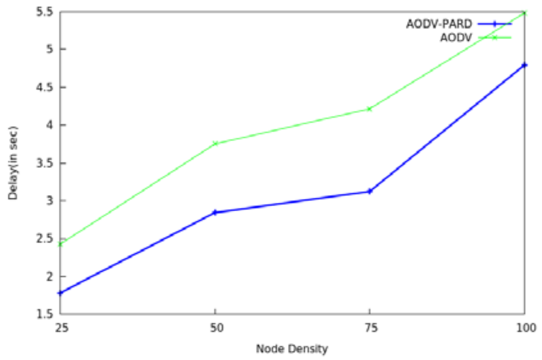
(a) Node density vs link failure count



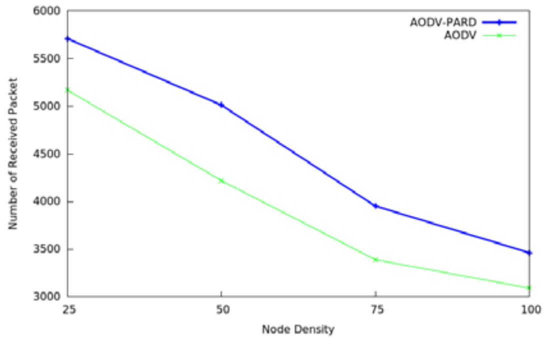
(b) Node density vs control overhead



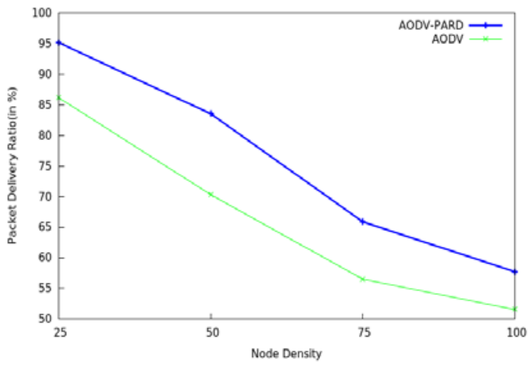
(c) Node density vs normalized overhead



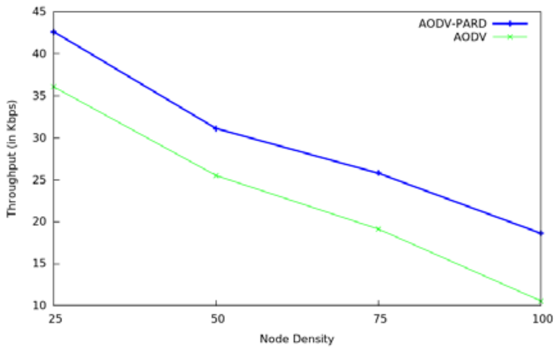
(d) Node density vs delay



(e) Node density vs number of received packet



(f) Node density vs packet delivery ratio

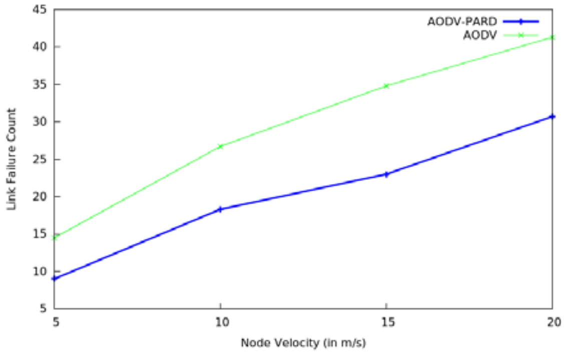


(g) Node density vs throughput

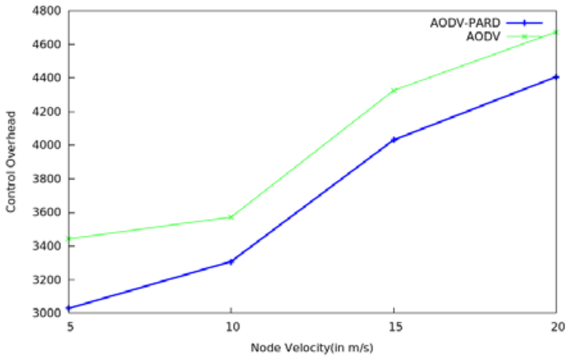
Fig.3. Performance analysis based on node density

B. Based on Node Velocity

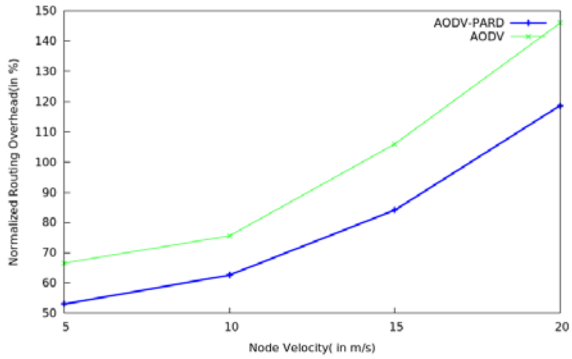
The AODV and AODV-PARD routing protocols are simulated with varying node velocity to investigate the effect of node velocity on the routing protocols. To achieve the results depicted in Fig.4(a) to Fig.4(g), the node velocity is adjusted while the other simulation variables are assumed to be constant. The pause time is set to *90 second* and the node density is set to *25*.



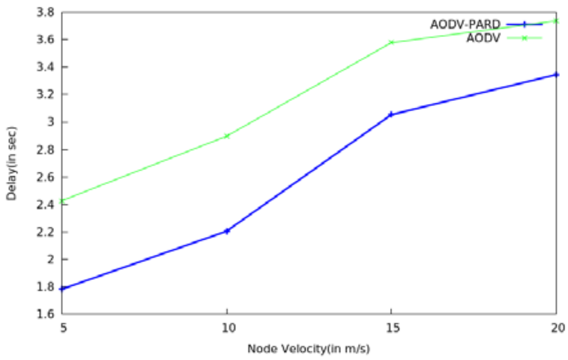
(a) Node velocity vs link failure count



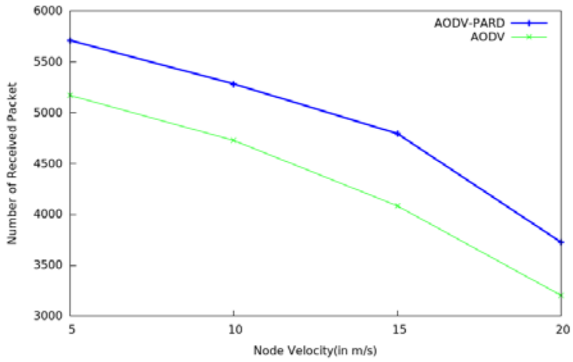
(b) Node velocity vs control overhead



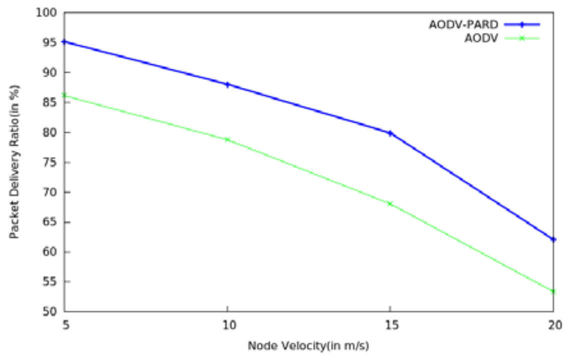
(c) Node velocity vs normalized overhead



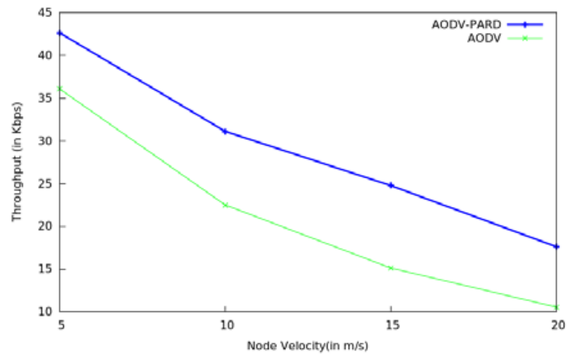
(d) Node velocity vs delay



(e) Node velocity vs number of received packet



(f) Node velocity vs packet delivery ratio

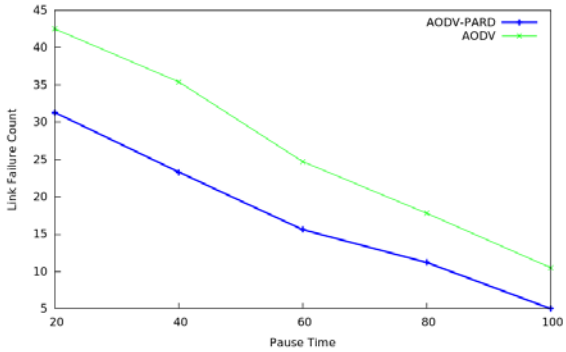


(g) Node velocity vs throughput

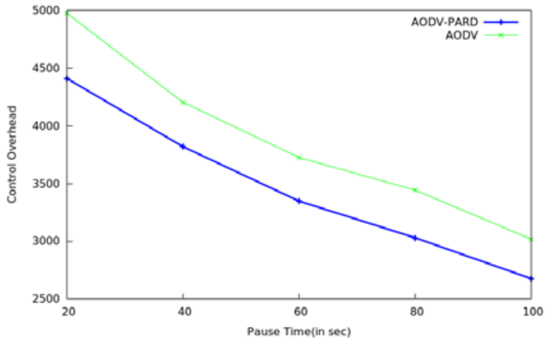
Fig.4. Performance analysis based on node velocity

In Fig.4(a), the result depicts that AODV-PARD has significantly less link failure count than AODV. This is because link failure prediction model assists in identifying alternate route proactively before the link failure and data packets are delivered via the alternative routes. Additionally, it has been shown that link failure count increases as node velocity increases.This is because, with increased mobility, more links are established and thus more routes are broken.

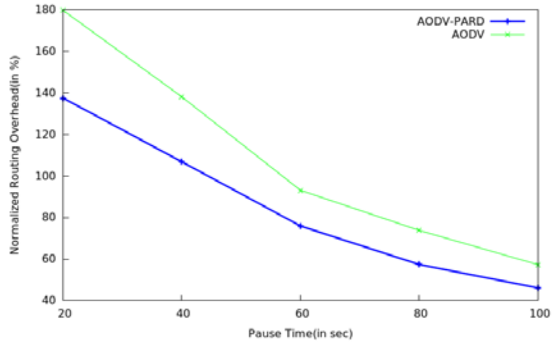
Fig.4(b), Fig.4(c) and Fig.4(d) have shown that AODV PARD has a significantly lower control overhead, normalized routing overhead and delay than AODV, whereas Fig.4(e), Fig.4(f) and Fig.4(g) indicate that AODV-PARD has a higher packet delivery ratio, packet count and throughput than AODV. Adittionaly, AODV-PARD and AODV, have higher control overhead, normalized routing overhead and delay; have a lower number of received packets, packet delivery ratio and throughput as node velocity increases. This is due to the link failure count being proportional to control overhead, normalized routing overhead and delay directly; it is proportional to the number of received packets, packet delivery ratio and throughput indirectly.



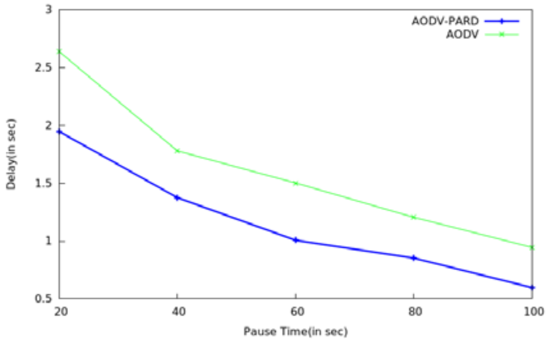
(a) Pause time vs link failure count



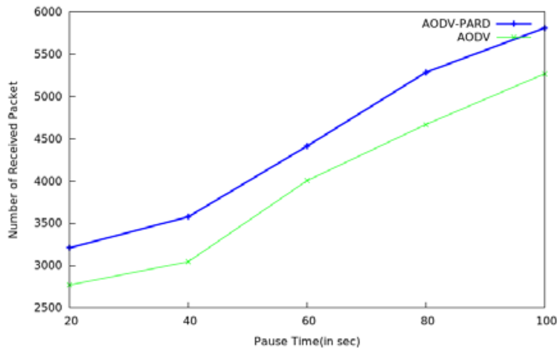
(b) Pause time vs control overhead



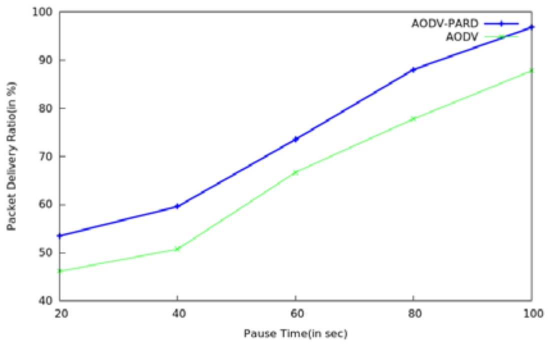
(c) Pause time vs normalized overhead



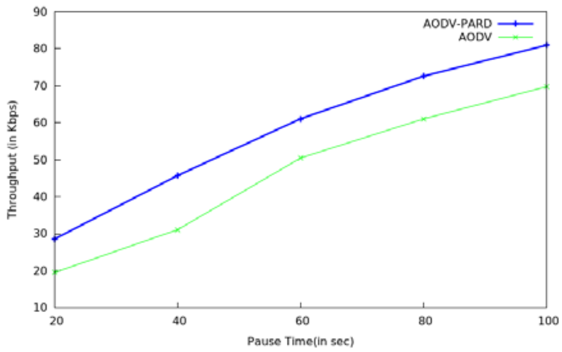
(d) Pause time vs delay



(e) Pause time vs number of received packet



(f) Pause time vs packet delivery ratio



(g) Pause time vs throughput

Fig.5. Performance analysis based on pause time

C. Based on Pause Time

To analyse the impact of mobility on AODV-PARD and AODV, the pause time is varied as *20, 40, 60, 80* and *100 seconds* and the remaining parameters are kept constant as node density is *25* and node velocity is *5 meters/second*. Fig.5(a) to Fig.5(g) demonstrates the results in the graphical format.

As illustrated in Fig.5(a), the results indicates that AODV-PARD has a substantially lower link failure count than AODV. This happens because, with AODV-PARD, alternate routes are identified well in advance of a link failure and data packets are transmitted over the alternate route. Futhermore, the results show that the number of link failures decreases as pause time increases. This occurs because a larger pause time decreases node mobility, which minimises the number of link failures; thus, increasing the pause time improves performance.

Fig.5(b), Fig.5(c) and Fig.5(d) therefore demonstrate that AODV PARD has a much-reduced control overhead, normalized routing overhead and delay than AODV, whereas Fig.5(e), Fig.5(f) and Fig.5(g) illustrate that AODV-PARD receives more packets, has a higher packet delivery ratio and has a greater throughput than AODV. Additionally, both AODV-PARD and AODV have a lower control overhead, normalized routing overhead and delay; they also have a higher number of received packets, packet delivery ratio and throughput as pause time increases. The reason behind this is, the link failure count is directly proportional to control overhead, normalized routing overhead and delay; it is indirectly proportional to the number of received packets, packet delivery ratio and throughput.

6. Conclusions

This paper, outlined AODV with a proactive alternate route discovery routing protocol. An estimation function predicts the link failure by utilizing the signal strength of five consecutive packets and then proactively initiates alternate route discovery before the failure. We investigated and compared the performance of the proposed AODV with proactive alternate route discovery to that of conventional AODV using simulations. The following are the major advantages of the AODV-PARD routing protocol as determined by rigorous simulation analysis.

- It minimizes the number of link failures by diverting the traffic from alternate path before link failure.
- Additionally, it outperforms conventional AODV in terms of control overhead, normalized routing overhead, end-to-end delay, the number of received packets, packet delivery ratio and throughput.

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