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Optimizing Power Control and Link Availability Prediction in Software Defined Mobile Ad-hoc Networks

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***Abstract*:** Routing offers a challenge in MANET because mobility of nodes will motivate frequent link breaks and therefore frequent modifications in topology due to mobility, leading to frequent route exchange. Accordingly, QoS provisioning for software application turns into a challenge. When a link break takes place, the route has to be repaired locally or a new route needs to be found. All through change in route discovery after link break, packets may be dropped. This results in unnecessary wastage of the scarce node resources along with battery energy. In this paper, a novel mechanism has been proposed to predict the duration of latest route availability. This approach pursuits to enhance the Quality of Service (QoS) by predicting a link failure earlier than its incidence and routing the packets via an alternate path, while nodes are moving dynamically in Mobile Ad-hoc network. Availability of route is determined by using availability of links among the devices which are making the route. To estimate path's future availability, the prediction is mandatory for those links. Availability of a link among nodes depends on the mobility of nodes, energy intake by the nodes, channel fading and shadowing etc. However, node mobility is major contributing issue for link failures. The proposed mechanism for predicting the link is used to estimate the active link availability to the neighbors. Primarily based on this data, when link failure is anticipated among two nodes, proactively an alternative path is building up earlier to link breaks. This reduces the packet drops (data) and hence the recovery time. With the proposed approach the nodes life time will be improved and performance of the network will be improved.

Keywords: PCLP, PDR, SDMANET, QoS

I. INTRODUCTION

Regular modifications in topology due to mobility and very limited battery power of the mobile devices are the important thing in the mobile ad-hoc networks. The depletion of energy source may be a reason for early unavailability of nodes and hence links in the network. Frequent route breaks occur due to the mobility and it impacts the performance of the running applications.

Untethered connectivity using wireless interfaces prefer to be present with each and every node with in the network. Normally mobile nodes will depend on battery power backup for their operations. It's desirable to reduce the energy utilization in those nodes. Further, this problem becomes important when the battery backup of the node is exhausted, in this scenario it cannot transmit or receive data. It also impacts on network's connectivity in ad-hoc networks because of even intermediate nodes are important to maintain connectivity. As soon as any one of the middle or intermediate nodes dies, the complete link need to be construct again. This results in large delay, wastage of node resources along with battery strength thereby hampering the throughput of the whole network [1]. Similarly, mobility offers the challenges in the form of constantly variable topology and for this reason requiring a complex and efficient energy routing mechanisms. Wireless networks can be used mostly by the personnel communication devices which people can carry with them [2]. These small, always constantly connected personnel devices will lead to new applications. For running most of these apps on resource limited devices, one needs efficient networking stack in the mobile devices. To improve the overall performance further, the layered software components is broken by allowing layers to get access data structures from non-immediate layers. This technique is referred as multi-layer optimization. The nodes can be mobile, consequently the links inside the most efficient path from source to the final node may break either because of mobility or a lot less battery power.

We proposed Power Control and Link Prediction (PCLP) in mobile ad-hoc networks that gives a mixed solution for power optimization in addition to link availability. The simulated results give the proposed power control and link prediction approach improves the throughput, packet delivery ratio (PDR) through earlier prediction of link breaks and commencing the route repair. Moreover, it reduces communication interruption time, routing overheads, power consumption and delay. For that reason, the proposed PCLP scheme will increases the network lifetime and its functionality.

The section II of this paper will describes the power control and link availability among the nodes. The next section deals with the proposed algorithm for link prediction. The simulation results and analysis has discussed in section IV. At last the conclusion and future work has presented.

II. POWER CONTROL AND LINK AVAILABILITY PREDICTION

The proposed PCLP gives a blended solution for power consumption in addition to link availability which incorporates the effect of optimum energy to transmit and received signal strength-based link availability estimation with AODV [3] routing protocol using this approach. This approach proposed to use adequate transmit power for transferring the packets to its neighbors to increase the link availability. The power to transmit and received signal level of the packets are the interaction parameters to the blended solution for energy conservation and to form a reliable route with improved link availability and as a result the routes amongst sources and destinations. The interactions are in between non-adjacent layers within the protocol stack. It improves the throughput, packet delivery ratio through earlier prediction of link breaks and starting up the path repair. It additionally reduces communication interruption time, routing overheads, end-to-end delay and energy consumption by means of use of multi-layer interaction.

Figure 3.1 demonstrates multi-layer interactions [4] in between physical and network layers. The signal power received is utilized by network layer to initiate the process to find the new path.

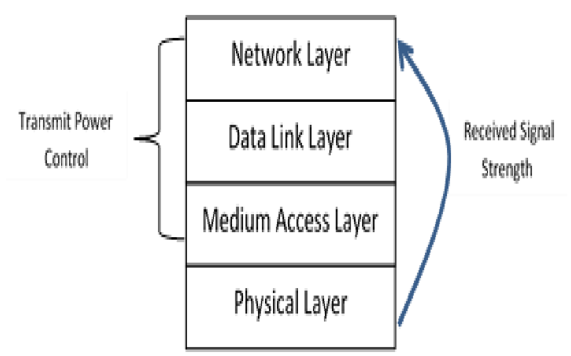

Fig 1. Multi-Layer Interactions at node

Multi-layer-based method for link availability prediction (PCLP) increases the networks as well as nodes' lifetime and ability by way of combining the effect of most appropriate transmit power for transmitting several packets like RTS, CTS, ACK and DATA and link availability time estimation. Furthermore, route formation before the link break to support Quality of service (QoS) necessities of applications [5].

A) Link Prediction

In conventional cellular and wired-community routing algorithms, a change of route happens when a link along the route fails or any other shorter route is found. A link failure is pricey because several retransmission timeouts are needed to discover the failure and then a new path direction needs to be located, which leads to postpone (delay) in restoration. For the reason that paths fail so irregularly in wired networks, this isn't an important issue but the same procedure is followed by the routing protocols in ad-hoc networks.

In this, we are proposing an algorithm to predict the link the time after which an energetic or active link will break. This is executed by time estimation at which signal strength level of the data packets obtained will fall underneath a threshold strength. The received power level underneath the threshold shows that the two neighboring nodes are shifting far from each other's transmission range. The link destroy (break) prediction warns the source earlier to path break and the source may rediscover a new route in advance. In this method, 3 consecutive measurements of signal energy of packets acquired from the previous node are used to expecting the link failure with Newton divided distinction approach [6,7]. The general expression for interpolation polynomial is.

$$f(x) = f(x_0) + (x - x_0) f(x_0,x_1) + \cdots + \left(p_i^{\,n-1} = 0\,(x - x_i) \right) f(x_0,x_1,\ldots x_n)$$

The acquired sign strengths of the latest three packets (data packets) and their incidence times are maintained by every receiver for all transmitters from which it's receiving. Let us assume three obtained data packets' signal energy strengths as p_1, p_2, p_3 and the time when packets arrived as t_1, t_2, t_3 instants respectively and p_r as the threshold signal level to be operative at the time t_p, and assumes that, it is possible to predict t_p. We assume that on the predicted time t_p, when acquired power strength reduces to threshold power, the link will damage. The threshold signal level p_r, is the minimum power receivable with the aid of the device.

Let us consider the at most transmission capacity of WaveLAN card in open environments is 250 meters in 900 MHz band. The threshold signal strength value p_r is 3.65×10^{-10} Watts. The anticipated (expected) signal level of the packets obtained can be evaluated as below, in which Δ and Δ^2 are first and 2nd divided differences respectively.

$$P_r = P_1 + (t_p - t_1)\,\Delta + (t_p - t_1)(t_p - t_2)\,\Delta^2 - \quad (3.1)$$

$$Pr = P1 + \frac{(t_p - t_1)(P_2 - P_1)}{(t_2 - t_1)} + (t_p - t_1)(t_p - t_2)\frac{\left(\frac{(P_3 - P_2)}{(t_3 - t_2)} - \frac{(P_2 - P_1)}{(t_2 - t_1)}\right)}{(t_3 - t_1)}$$
--- (3.2)

Let $A = \frac{(P_2 - P_1)}{(t_2 - t_1)}$ ------- (3.3)

$B = \left(\frac{(P_3 - P_2)}{(t_3 - t_2)} - \frac{(P_2 - P_1)}{(t_2 - t_1)}\right) / (t_3 - t_1)$ ----- (3.4)

The equation 3.2. becomes

$$Pr = P1 + (t_p - t_1)A + (t_p - t_1)(t_p - t_2)B$$ - (3.5)

Rearranging equation 3.5.

B

$$(B_p^2 + (A - Bt_1 - Bt_2)t_p + (P_1 - P_r - At_1 + t_1 t_2 B) = 0$$
------- (3.6)

This is of the form

$$at_p^2 + bt_p + c = 0$$ ---- (3.7)

where a = B

b = $A - Bt_1 - Bt_2$ and

c = $(P_1 - P_r - At_1 + t_1 t_2 B$

Therefore, the predicted time t_p at which link will fail is

$$t_p = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$ -------------- (3.8)

Routing protocol requires adequate amount of time to setup a new or possible alternate path, thus a parameter, critical time t_s, is incorporated. The critical time should be sufficient enough to send error message to next node towards the source of the packet and for source to discover a new route. The t_s have to be just smaller than link break time t_p. After time t_s, the node enters into the state called critical state and node must find an alternate route. When a link is anticipated to fail among the nodes, first the upstream node tries to find a direction or route to the destination. If such route isn't discovered within a fixed time called discovery period, a link failure caution is sent towards the sources whose neighbors are using the same link. To setup the restoration path, the source node can invoke the mechanism of route discovery. At time t_s, the received signal level is enough for sending caution message to the next node towards upstream and obtain an alternate route either by using local repair around the link which is to interrupt or by the way of establishing new paths from source. As nodes move outwards, signal level of the nodes drops. Consequently, we define link spoil (link break) whilst nodes are crossing the radio transmission range for first time and broken links are repaired domestically in k hops. The cost of *k* is, i. e. damaged links can be repaired in two hops. The proposed approach for local route repair tries to restore broken route domestically with minimum control overheads for recovery in faster manner.

The time for link availability can be estimated by using received signal level from the physical layer. The link break prediction will warn sources via the upstream nodes earlier to path break so that either the source node to upstream nodes may find the new direction to establish the path in advance for packet forwarding.

The decision-making process for link selection to form the path is as follows. The physical layer can access the received signal level and it is forwarded to the upper layers along with the signal so that this value can be used by these upper layers for calculations. Then passed to routing layer with control packets and stored in neighbor and routing tables. The calculation includes the estimating the time stamp at which the threshold power is above the received signal power. That is the decode power is above the received signal power level shows that the two neighboring nodes are moving away from the radio transmission range of each other's which leads to link break.

In this approach, three subsequent measurements of signal level of packets received from the previous node are used to predict the link failure. The received signal level of 3 latest data packets and their occurrence time maintained by each receiver for each transmitter from which it is receiving. Using three received data packets' signal power strengths as P_1, P_2, P_3, and the time when packets arrived as t_1, t_2, t_3 respectively and P_p instants as the decode signal strength (P_{decode}) at the time t_p, one can determine t_p using equation (3.6). Can be referred for the calculation of the value of t_p. We assume that at predicted time t_p, when received power level reduces to or less than decode power, the link will break. The expected signal strength of the received packets can be evaluated as below, where Δ and Δ^2 are first and second divided differences respectively.

$$P_p = P_1 + (t_p - t_1)\,\Delta + (t_p - t_1)(t_p - t_2)\,\Delta^2$$ --(3.5)

$$P_p = P1 + \frac{(t_p - t_1)(P_2 - P_1)}{(t_2 - t_1)} + (t_p - t_1)(t_p - t_2)\frac{\left(\frac{(P_3 - P_2)}{(t_3 - t_2)} - \frac{(P_2 - P_1)}{(t_2 - t_1)}\right)}{(t_3 - t_1)}$$
----- (3.6)

At time t_s, the node enters into the state called critical state and it should find alternate route. So that a warning message regarding the failure of link has to send to its upstream link whose neighbors are using this link. The route discovery mechanism has to be invoked by the path initiated or source node to setup restoration path. The power received at time t_s is represented as threshold power and this power is enough to send warning messages towards its source via an upstream node so that the source can discover an alternate path.

Algorithm 1: Link prediction algorithm

```
For each neighbor
When packet received
update record of (received power, time) for last three packets
if ((p1 > p2) and (p2 > p3)) then Prediction()
Prediction()
{    Estimate and update tp and update the ts, when node enters into critical state, prior to link
break    }
if (present time ≥ ts)
{    sent warning message to upstream node
     Sleep for fixed duration         }
On receipt of repair message
Set the route and link status as soon to be broken
local route repair()
local route repair()
{    Find the path to next node nj
     if (found a path in k hops within time)
          use this path for rerouting
   else
          Find the path to destination D
   if (path is found)
  {  Route the packet through new path,
     send the message to sources to find the shortest path.
  }
}
```

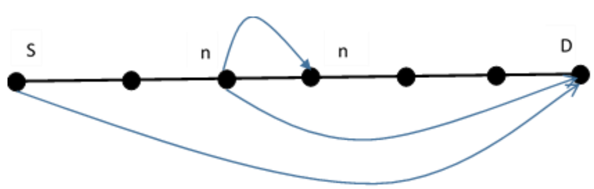

Fig 2 : Local Route Repair

B) Power Control:

At the MAC layer RTS, CTS, DATA and ACK are sent at adequate transmit energy level simply good enough to sustain a nice quality communication. The estimation is completed dynamically based on received signal level of RTS, CTS, DATA and ACK packets between links and for this reason, the sender can adjust its transmit power.

To maximize the battery existence of mobile nodes, the proposed protocol will work based on Adaptive Power Control MAC protocol in the sort of manner that the overall transmitted power is less and hence battery consumption is much less.

At MAC layer, RTS, CTS, DATA and ACK are dispatched at the optimum power. The header fields of RTS, CTS, DATA and ACK contain the power level to transmit which can be used to evaluate optimum power to ship a packet.

$$P_r = P_t\, G_t\, G_r\, (\lambda / 4\pi d_{ij})^2 \qquad \text{---- (3.1)}$$

Where in λ is the wavelength of provider or carrier, d_{ij} is the distance among sender and receiver. G_t and G_r are the gain of transmitting and receiving antennas respectively. The power of P_t is the transmit power of the packet. The header fields of RTS, CTS, DATA and ACK are modified to incorporate the transmission power level of the respective packets. While a node gets such packet, it also gets the transmission power level p_t, the obtained power p_r is calculated through the physical layer and the value is ship to MAC layer. Each node knows the minimal threshold energy $P_{threshold}$ at which the packet can be decoded nicely. Hence, we get the desired minimum transmission strength required in order to nicely decode the packet at the receiver.

$$P_{tmin} = P_{threshold} / G_t\, G_r\, (4\pi d_{ij} / \lambda)^2 * c \qquad (3.2)$$

However, we do not have records about approximate distance among the nodes. We can find out optimal transmission power by the equation

$$P_{tmin} = P_{threshold} * P_t * c / P_r \qquad . \quad (3.3)$$

$$P_{opt} >= P_{tmin} \qquad (3.4)$$

In which, P_{opt} is the optimum transmission power and is discrete level more than P_{tmin}, P_t and P_r are the transmission and obtained powers of the previous packet from that receiver to sender, respectively. C is a constant which is equivalent to 1.05 to compensate for the interference and noise.

Every node will hold a table to maintain so as to contain the optimal transmit power level required in order that the destination node might be capable of decode the packet efficiently and can initiate the process for link successes. The table could have two columns, one could have MAC address of the destination node and the other might be the power level. This table will be called the "Optimal Power Table". This table is small because it contains entries of only its neighbors. The optimal power entry format is shown in figure 3.

Node	Optimum Transmit

Figure 3: Format of Optimum Power Table

In this approach, we have used 3 threshold received signal strengths. They are threshold received signal strengths $P_{threshold}$, $P_{critical}$ and P_{decode} respectively. At $P_{threshold}$, the node enters into link prediction process. At $P_{critical}$, the node enters into the state called critical state, ship warning to the upstream node about link break and forms alternate path previous to link break. The P_{decode} is minimum strength allowed for the final or destination node to decode the packet.

In this design, the received signal level information obtained and evaluated at the physical layer and then, is transferred to the MAC layer for data transmission. The optimum reliable transmit power is computed using equation (3.3). This p_{opt} is available at each node in the optimized power table against the destination. In order to gain the optimum transmit or emanate power in the multi-layer design, the header fields of RTS, CTS, DATA and ACK are modified to incorporate the transmit power level of the respective packets.

Consequently, whilst a node receives such type of packet, it gets the transmission strength level p_t, the received electricity power p_r is accessed from the physical layer and the calculated transmit power is pass to the MAC layer. This indicates interaction between physical and MAC layers.

The node inserts an extra field called transmit power in RTS packet when it is sending so that the receiving node came to know and it will tune to this power while sending CTS packet. Subsequently, DATA and ACK packets will be transmitted from the sender and receiver respectively by using this optimum transmit power level.

III. ALGORITHM FOR PROTOCOL

The power levels set $P_t[L]$ used for the transmission, where L is an integer values ranges from 1 to 7. The transmit power $P_t[L]$ is the maximum power level and the number of power levels in the set is 7.

A. Transmitter:

1. *Let Pt[L] = 2.818,*
2. *Check the optimum power table at the transmitter node for the receiver node address and its stored optimum transmit power value ,*
3. *If node entry is available, then $P_t[L] = P_{tt}$ else $P_t[L] = 2.818$,*
4. *Add this power value in RTS header and send RTS with this power level $P_t[L]$,*
5. *Receive CTS packet, observe its received power and extract transmit power. The node calculates optimum transmit power for DATA packet,*
6. *Update optimum power table,*
7. *Add the power level in the DATA packet header and send the DATA packet at optimum transmit power level,*
8. *Receive ACK,*
9. *End.*

B. Receiver:

1. *For each neighbour,*
2. *On receipt of a packet,*
3. *If ($P_r > P_{threshold}$) then Powercontrol ()*
4. *Else*
5. *{ Update record of (received power, time) for last three packets,*
6. *If ((P1 > P2) and (P2>P3)) then Prediction (),*
7. *Prediction ()*
8. *{*
9. *Estimate and update the t_p, and update the t_s, when node enters into critical state, prior to link break*
10. *}*
11. *If (current time >= t_s)*
12. *{*
13. *Sent warning message to upstream node,*
14. *Sleep for fixed duration.*
15. *}*
16. *On receipt of repair message,*
17. *Set the route and link status as soon-to-be-broken,*
18. *}*
19. *Powercontrol ()*
20. *{*
21. *Receive RTS,*
22. *Observe the receive power, extract the transmit power and then calculate the optimum transmit power for the CTS packet. Update optimum transmit power table with power level,*
23. *Insert the optimum transmit power in the CTS header and send the CTS packet at the same power level,*
24. *Receive DATA packet,*
25. *Include the optimum power level in the ACK packet header and send the ACK packet at this transmit power level,*
26. *}*
27. *End.*

IV. SIMULATION AND RESULTS

We simulated AODV routing protocol, AODV with link prediction (AODV/LP) and reliable power control with link prediction (PCLP) using ns-3 [8]. In the simulations, we have varied 3 parameters – node velocity, network load (rate of technology of packets) and number of nodes in a given location. The exact simulation parameters are stated in table 5.1. Several simulations had been run with same parameters and average of observed values changed into taken to minimize the estimation error.

A) Simulation Parameters

Two-ray radio propagation model is used. We've used seven transmit energy levels. Three parameters viz. node velocity, network load and node density had been varied inside the simulations. Network load is the rate of generation of packets inside the network.

Table 3.1 Simulation parameters for PCLP

Traffic Pattern	Constant Bit Rate
Simulation Time	900 Seconds
Total Connections	20,25,30,35,40,45,50
Packet Size	512 Bytes
Velocity	5,10,15,20,25,30 meter/sec
Pause Time	10 Sec
Simulation Area	1500m by 300m
Total Nodes	25,50,75,100 and 125

B) Performance Metrics

The overall performance of protocols was evaluated in terms of average interruption time, overhead packets, power consumption, throughput, packet delivery ratio and end-to-end delay as characteristic of node mobility, rate of packets generation and node density. Constant bit rate (CBR) sources are assumed inside the simulation.

Average interruption time is the time throughout which ongoing communications are interrupted.

Routing overhead is the wide variety of routing overhead packets which might be generated inside the network to transport the data packets.

Power consumption (in Joules) per 1 kilobyte data delivered is calculated as the entire amount of transmitting and receiving consumption over all flows divided via the whole data delivered with the aid of all the flows. The energy consumption of all the packets RTS, CTS, DATA and ACK are considered.

Throughput is the number of kilobytes transferred successfully with the aid of the sender to the receiver correctly.

Packet delivery ratio is the ratio of the data packets delivered to the destination to those generated by using the CBR sources. The better the value higher is the performance.

Average end-to-end delay of data packets consists of all viable delays due to buffering in the duration of route discovery, queuing at interface queue, retransmission delays at MAC layer, propagation and transfer time.

C) Simulation Analysis

The simulation results are obtained for AODV, AODV/LP and PCLP. The velocity is varied in discrete steps as five, 10, 15, 20, 25 and 30 meters/second for a fixed network of size 50 nodes and pause time of 10 seconds in figures 3.3 and 3.4. Fig 3.3 shows the evaluation of the average interruption time in PCLP, AODV/LP and AODV schemes. It shows that PCLP shows least average interruption time as compared to AODV/LP and AODV. That is due to the fact PCLP uses smaller transmission range for that reason concurrent transmission of packets in addition to uses backup path in case of path failures for restoration of path as consequence outcomes in lowest interruption time as compared to AODV/LP and AODV. But, AODV, AODV/LP and PCLP give increasing average interruption time with growth in node velocity because faster mobility of nodes reasons more route unavailability. In addition, more route unavailability brings higher interruption time.

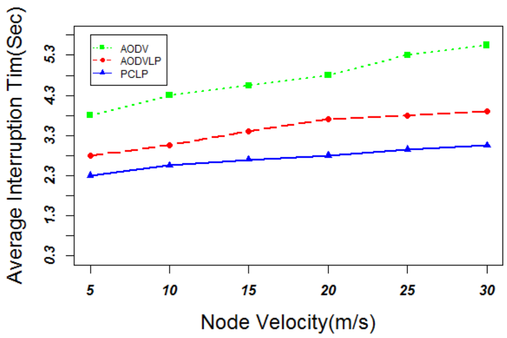

Fig 3.3. Average interruption time vs node velocity

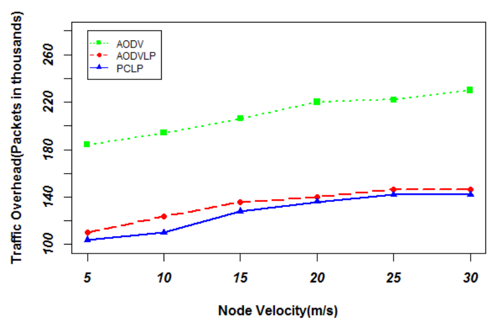

Fig 3.4. Routing overhead vs node velocity

Figure 3.4 shows that the overhead packets are least in PCLP as compared to AODV/LP and AODV, due to the fact more packets are transferred simultaneously because of smaller carrier sensing range in addition to availability of alternate routes in case of route failures caused due to better node mobility. However, in PCLP, AODV/LP and AODV schemes, the routing overhead packets increase with growth in node velocity. This takes place due to the fact increase in node velocity will increase greater path unavailability for fast shifting nodes. Therefore, overheads of latest path discovery lead to increase in the routing overhead packets.

The packets generation rate is varied and other simulation variables are kept consistent for a fixed network size of 50 nodes and pause time of 10 seconds and speed as five meters/sec in figures 3.5, 3.6, 3.7, 3.8 and 3.13. Fig 3.5 shows that in PCLP, the average interruption time is least as compared to AODV/LP and AODV because of availability of path for increasing packets flow. The interruption is least in PCLP as RTS, CTS, DATA and ACK packets are transmitted at lower power as well as availability of restoration paths in case of link failures. However, AODV, AODV/LP and PCLP provide growing interruption time as packets generation rate increases. At low packet generation rate, less packets would be contending and at higher network loads, more packets could be contending for the transmission and thus, more interruption time. Consequently, average interruption time will increase with increase in packet generation rate.

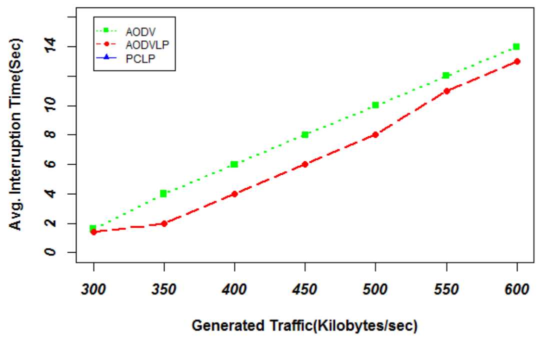

Fig 3.5. Average interruption time vs packet generation rate

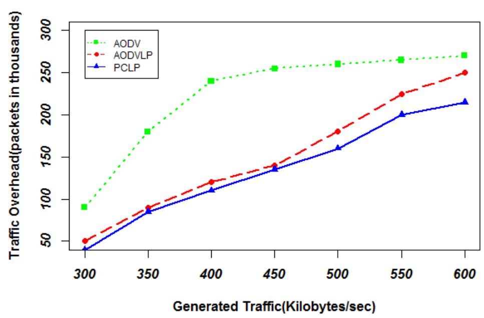

Fig 3.6. Routing overhead vs packet generation rate

In figure 3.6, The PCLP scheme generates least overhead routing packets as compared to AODV/LP and AODV schemes due to concurrent transmission of the packets due to lower transmit power and prior route discovery before link failure, which avoids retransmission of the packets in the network. In AODV, AODV/LP and PCLP, the routing overhead packets are increasing with growth in number of generated data packets because this may increase contention and collisions. The result shows that when packet generation rate was increased there is an increase in packet overhead because more data packets are contending for the transmission channel thus more overhead packets are generated for retransmission of the packets.

Figure 3.7 shows the comparison of the throughput of AODV, AODV/LP and PCLP. It suggests that PCLP achieves maximum throughput in comparison to AODV/LP and AODV schemes. This is because of the fact PCLP uses smaller carrier sensing range in comparison to AODV/LP and AODV, consequently large amount of nodes can transmit concurrently. Results show that throughput is the higher in AODV/LP in comparison to AODV. It happens due to the fact in PCLP and AODV/LP, moreover alternative routes are located in advance earlier than a link failure and supplies a message thru alternative route. However, PCLP gives increasing throughput as packet generation rate will increase and saturates. The throughput stays constant after a particular point. As at low packet generation rate, lots less amount of packets is probably contending for the transmission and at better network loads, due to reduction in energy additionally reduces the number of deferring nodes, and as a end result, more data can be added in line with joule, therefore throughput will increase linearly and saturates at higher packet generation rate.

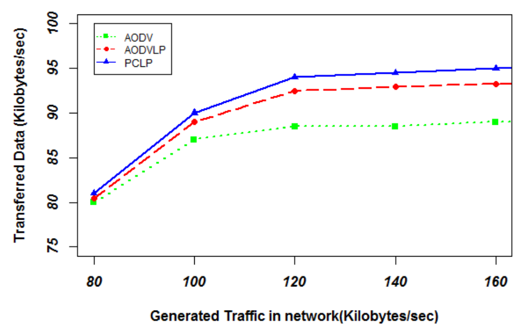

Fig 3.7. Throughput vs packet generation rate

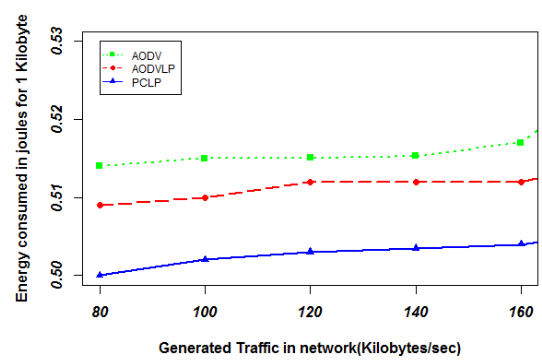

Fig 3.8. Average energy consumption in joule per communication of 1 Kbyte of data vs packet generation rate

Figure 3.8 indicates variation of power consumed per successful conversation of 1kilobyte of information with growth in packet generation rate. Outcomes display that power consumption per one successful communication of one kilobyte of information is lowest in PCLP as compared to AODV/LP and AODV.

PCLP is least power consuming in comparison to different schemes because it makes use of decrease power for communication of RTS, CTS, DATA and ACK packets and link successes are also found and avoiding retransmissions of packets. But, PCLP, AODV/LP and AODV give increasing average energy consumption as network load will increase, on account that extra packets are generated and contending inside the network and therefore those packets are ship to the destination locations, consequently greater energy is consumed in successful conversation of these packets. The network size is varied and different simulation variables are kept constant with pause time as 10 seconds and velocity as 5 meters/sec in figures 3.9, 3.10, 3.11 and 3.12. In figure 3.9 suggests that the throughput per node is excellent in PCLP in comparison to AODV/LP and AODV. This happens because in PCLP scheme, concurrent transmission due to use of optimum transmit power, that's lesser as well as proactive route discovery in case route failures and consequently more data is delivered. The throughput in keeping with node is decreasing in all of the schemes with growth in number of nodes due to the fact this increases contention and collisions. At very low density, all the 3 schemes give higher throughput as contention and collisions are less. At high density, all the three schemes give lesser throughput as contention and collisions are more because of more neighboring nodes within the vicinity.

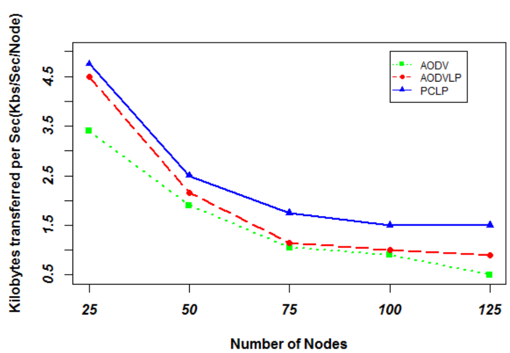

Fig 3.9. Throughput per node vs no. of nodes

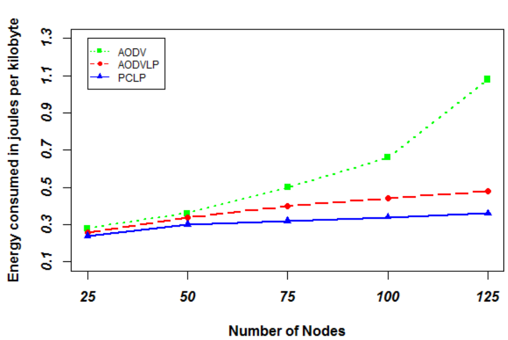

Fig 3.10 Energy consumption per communication of 1 kilobyte data vs no. of nodes

The electricity consumption will increase in case of all the schemes because the node density will increase, contention and collisions also increase. But the energy consumption of the PCLP is least among all the schemes throughout the density variation thereby making it better protocol. Figure 3.11 show that the variation of packet delivery ratio with increasing node density. The outcome show that packet delivery ratio is fine PCLP in comparison to AODV/LP and AODV. It happens because in PCLP, concurrent transmission takes place because of spatial reuse of the channel as a consequence of lower transmit power of the packets, in addition to PCLP and AODV/LP schemes find out alternative routes before the route failures, and extra data is effectively brought to the destination. However, PCLP, AODV/LP and AODV deliver decreased delivery ratio as node density will increase, because it reasons more contentions and collision due to more neighboring nodes in the vicinity and therefore, decreases delivery ratio by retransmitting the packets more than once.

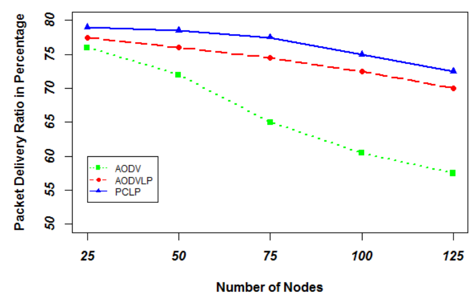

Fig 3.11 Delivery of packets vs no. of nodes

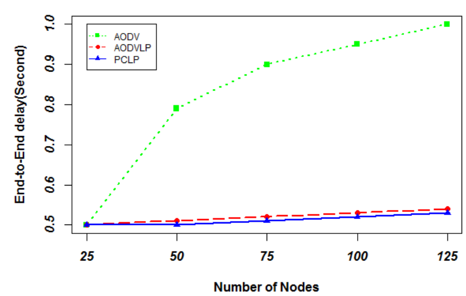

Fig 3.12. End to end delay vs no. of nodes

The end-to-end delay is an average of difference between the time a data packet is originated by an application and the time the data packet is acquired at its destination. Fig 3.12 suggests lowest end-to-end delay in PCLP in comparison to AODV/LP and AODV due to the PCLP takes care of concurrent transmission of packets because of decrease transmit power for RTS, CTS, DATA and ACK further to prior route discovery in case of route failures. The end-to-end delay is lower in AODV/LP as compared to AODV due to prior route discovery in case of path failures. At low density, the delay is low in all schemes and it increases with growth in density due to the fact high node density increases contention and collisions hence result in retransmission of packets.

V. CONCLUSION

In this paper, the proposed combined solution deals with link availability and power control in ad-hoc networks. This approach minimizes the power consumption to get long battery life apart from link prediction which will be used to predict the future availability of the link between nodes. The link prediction is based on the received signal of the last three consecutive data packets and threshold signal strength.

The performance of the proposed protocol PCLP (Power Control and Link Prediction) is compared with AODV and AODV/LP in terms of throughput, battery life and overhead. This also improves network lifetime.

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