PPCLSS: Probabilistic Prediction Coefficient Link Stability Scheme based Routing in MANETs

Article · April 2015

1 author:

Deva Priya
Sri Eshwar College of Engineering

PPCLSS: Probabilistic Prediction Coefficient Link Stability Scheme based Routing in MANETs

Deva Priya. M
Sri Krishna College of Technology, Coimbatore, Tamilnadu, India.
meetdevapriya@gmail.com

Priyanka. P
Sri Krishna College of Technology, Coimbatore, Tamilnadu, India.
priyankacse29@gmail.com

ABSTRACT - Ensuring the stability of a link in MANETs is mandatory to prolong the lifetime of a network. Probabilistic Prediction Coefficient Link Stability Scheme (PPCLSS) based routing is proposed for MANETS. Link loss is found based on the number of packets forwarded from a mobile node and the average dynamic distance between two mobile nodes with the mobility proportion (K). The overall path stability of the route is manipulated as the weighted sum of Energy utilized by a node, link loss and average lifetime of a path. The scheme outperforms the existing schemes - Stability and Hop count based Algorithm for Route Computation (SHARC), Link-StAbility and Energy aware Routing protocol (LAER) and Prediction based Link Stability Scheme (PLSS) in terms of Packet Delivery Ratio, Throughput, Control overhead and total overhead.

Keywords - MANET, Link stability, Residual Energy (RE), Path lifetime.

I. INTRODUCTION

With the development of wireless communication technology, two basic wireless network models have been developed for the wireless communication system. The fixed backbone wireless model consists of a large number of Mobile Nodes (MNs) and relatively fewer, but more powerful, fixed nodes. The communication between a fixed node and a MN within its range occurs via the wireless medium. However, this requires a fixed permanent infrastructure. Another system model is Mobile Ad-hoc NETwork (MANET) which is a self-organizing collection of MNs that form a temporary and dynamic wireless network on a shared wireless channel without the aid of a fixed networking infrastructure or centralized administration.

In wireless communication systems, there will be a need for rapid deployment of independent mobile users. Such network scenarios cannot rely on centralized and organized connectivity, and can be conceived as applications of MANET [1]. MANETs are suitable for applications in which no infrastructure exists such as military battlefield, survivable, efficient, dynamic communication for emergency/rescue operations, disaster relief efforts, vehicular communications and mining operations. In these applications, communication and collaboration among a given group of nodes are necessary.

MANET is a collection of mobile devices equipped with a transmitter and receiver communicating with each other via wireless links from time to time. Base Stations (BSs) are not involved in such an environment. A MANET is an autonomous collection of mobile users that communicate over relatively bandwidth constrained wireless links. In comparison to fixed wireless networks, there is no master slave relationship that exists in a MANET. Each node acts as a router and nodes rely on each other to established communication [2].

Other applications of MANETs include battlefields or major disaster areas where networks need to be deployed immediately but BSs or fixed network infrastructures are not available. Moreover, in a military environment, preservation of security, latency, reliability, intentional jamming and recovery from failure are significant concerns [3]. Military networks are designed to maintain a low probability of intercept and/or a low probability of detection. The set of applications for MANETs is diverse, ranging from small, static networks that are constrained by power sources to large-scale, mobile and highly dynamic networks. The design of network protocols for these networks is a complex issue. Regardless of the application, MANETs need efficient distributed algorithms to determine network organization, link scheduling, broadcasting and routing.

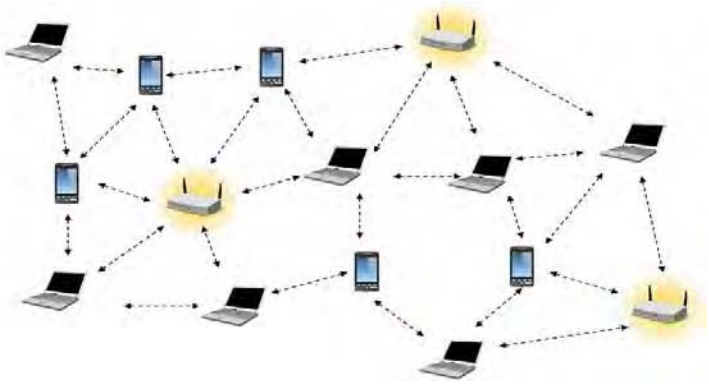

Figure 1. Basic Structure of an Ad Hoc Network

Basic structure of mobile ad hoc network is shown in the Fig. 1. MANET is defined to be purpose-specific, autonomous and dynamic. Due to considerations such as radio power limitation, channel utilization and power-saving concerns, a mobile host may not be able to communicate directly with other hosts in a single-hop fashion. In this case, a multi-hop communication occurs, where the packets sent by the source host are relayed by several intermediate hosts before reaching the destination host. Each node directly communicates with only those nodes that are in its communication range. Intermediate nodes forward messages to the nodes that are at more than one hop distance from the source.

The control and management of MANET is distributed among the participating nodes. Each node is responsible for forwarding the packets to other nodes in the networks. The nodes cooperate among themselves to implement network routine functions such as security. Since the nodes are mobile, the topology of the network changes constantly.

Moreover, the connectivity among the hosts varies with time. In most cases, MANETs operate on low power devices. Normally, these devices have low CPU processing capability and small memory sizes, thus affecting the capability of the MANET to reach other devices.

Since the nodes are mobile, the network topology may change rapidly and unpredictably over time. The network is decentralized; where all network activity including discovering the topology and delivering messages must be executed by the nodes themselves. i.e., routing functionality will be incorporated into mobile nodes.

Factors such as variable wireless link quality, propagation path loss, fading, multi-user interference, power expended and topological changes are the issues to be dealt with. The network should be able to adaptively alter the routing paths to alleviate these effects. Hence, nodes prefer to radiate as little power as necessary and transmit as infrequently as possible, thus decreasing the probability of detection or interception. A lapse in any of these requirements may degrade the performance and dependability of the network.

The advantages of ad hoc networks include:

- No necessity for a BS
- Independence from central network administration
- Easier temporary setup
- Self-configuring - nodes are also routers
- Self-healing by continuous re-configuration
- Scalable - accommodates more number of nodes
- Flexible - able to access the internet from many different locations
- Well suited for free unlicensed spectrum

A. Routing

Routing is the most fundamental component in networks to support data communications. A routing protocol is the mechanism by which user traffic is directed and transported through the network from the source node to the destination node. The main objective is to maximize network performance from the application point of view of application requirements, while minimizing the cost of network itself in accordance with its capacity.

Within a wireless medium, it is even more crucial to reduce the transmission overhead and power consumption. Multicasting can be used to improve the efficiency of the wireless link when sending multiple copies of messages to exploit the inherent broadcast property of wireless transmission. So multicasting plays an important role in MANETs.

II. RELATED WORK

In MANETs, energy consumption, QoS, exposure to attacks and link stability are some of the critical issues that are to be considered. Stability of links play a vital role as it leads to increased rerouting which further escalates routing overhead. Multicasting reduces routing overhead. In [4], a multicasting routing protocol that uses received signal strength as a metric to estimate link stability is proposed. Signal to Interference plus Noise Ratio (SINR) at every node varies with respect to senders. It is used to determine a reliable path that is likely to mitigate link failures and reduce end-to-end delay. Best link between nodes with high probability of longer lifetime is chosen.

One critical issue for routing in MANETs is how to select a stable path that can last longer since mobility leads to frequent breaking of radio links. In [5], initially, a link stability prediction model that uses the relative motion and the distance between two neighbor nodes to evaluate the mean link duration used to predict link stability is proposed. Then, a Link Stability Prediction-Based Routing (LSPR) algorithm is proposed, in which the mid-nodes forward RREQs after some delay, which is decided by the mean link duration. In addition, a forwarding rule which can reduce the number of RREQs forwarded by receding neighbor nodes is designed. An analytical method that unveils the explicit relationship between mean link duration and the distance between two neighbor nodes is presented. Based on the relationship, we can predict the link stability denoted by mean link duration.

A link becomes unstable due to the random characteristics of the wireless channel and/or the mobility of nodes. Wang et al., [6] consider the instability due to mobility and propose a scheme to predict the link stability in mobile scenarios of MANETs. The prediction scheme is based on link connectivity changes performed in the network layer, without the need of low layer data. It is assumed that the link connectivity follows the continuous-time Markov chain model and the case of non-stationary movements is considered. A method to estimate the transition rates of the link connectivity model is proposed. The stability of the link is evaluated based on the transition rates. The prediction scheme is derived analytically and no prior information about parameters of the mobility model is required.

Statistical predictions based on the node movement are made in [7, 8] and link stability probability is defined based on the random mobility model.

A formal model to predict the lifetime of a routing path based on the random walk mobility and prediction technique is proposed in [9]. It considers a probability model derived by dividing the area into cells where mobile nodes move and observations of node movements are made in these cells. Transition probabilities are calculated and a state-based model of the movement among the cells is considered. The connection between a mobile node in a cell and other mobile nodes among its neighbor cells is considered as the state of the wireless link.

In [10], the link stability probability is determined by considering the signal stability. However, this approach is not suitable as it assumes that the signal strength can be affected by environmental conditions and its value can change a lot also for the same distance. This determines the fluctuations in the radio signal measurement, producing erroneous considerations on the link stability.

A routing protocol called Power Efficient Reliable Routing protocol for MANETs is proposed in [11]. This algorithm applies the following metrics for path selection. The estimated total energy to transmit and process a data packet, The residual energy and the path stability. Route maintenance and route discovery procedures are similar to the DSR protocol [11], but route selection is based on the three aforementioned metrics.

In[12, 13], the authors evaluated the performance of some path stability-based routing protocols, that is the Associativity-Based Routing (ABR), Flow-Oriented Routing Protocol (FORP)and Route-life time Assessment-Based Routing protocol (RABR). In [14], a multi-objective mathematical formulation of a routing scheme that considers two metrics namely, stability and energy is proposed. Only the optimization problem is formulated and there is no analysis on the protocol management and performance.

Rango et al., [15] have propounded a Link-StAbility and Energy aware Routing protocol (LAER) to make a correct balance between link stability and energy efficient. Each node broadcasts HELLO packets to all its neighbors that are in its communication range. Each node in LAER maintains a table of its direct neighbors. When a node receives a HELLO packet, it updates the information of the neighbor, if the neighbor ID is already present in the table or adds neighbor information, if it is a new neighbor.

Identifying stable paths helps in reducing the control traffic, number of connection disruptions and also in conserving power. In [16], Greedy Perimeter Stateless Routing (GPSR) and LAER designed for MANETs)are implemented for WiMAX networks and their performance is evaluated. Further, a novel Cross-layered Path Stability based Routing protocol (CPSR) is proposed to find a stable path based on Residual Energy (RE), Received Signal Strength Indicator (RSSI) and Signal-to-Noise Ratio (SNR).

A stable link from the available links for a reliable route in a multicast routing protocol is found in [LSMRP]. In [17, 18], the route is established on the basis of minimum hop count without any consideration of link quality.

As a result, a link that is likely to be disconnected soon could be part of the route. Such a link is not of good quality as network connection is disrupted at short interval(s). Limited bandwidth, resource constraints and dynamic topology necessitates development of a simple, scalable, robust and energy efficient routing protocol for multicast environment.

Auxiliary equipments are used in [19] – [21] to predict the link stability. Nodes equipped with GPS or sensors can obtain the detailed information of motion, such as velocity, direction and location.

Avoiding congested links cannot improve end-to-end delay. Node energy [22] is chosen as a metric to select forwarding group in multicast routing protocol to make a reliable path for data communication. Link stability can be estimated on the basis of these parameters and by avoiding congested links.

Links can be unstable because of the random property of the wireless channel, such as fading, shadowing or noise, or the mobility of nodes in the network [23].

In [24], received power is used to calculate the distance between two neighboring nodes. When the distance is smaller than the threshold, the link is stronger and weaker otherwise. The routing algorithm uses the strongly connected link to construct path preferentially.

In [25], a link stability prediction scheme based on the random walk or random waypoint model that requires the knowledge of some parameters of the mobility model is proposed. These parameters are of prior knowledge or estimated using other techniques that usually require the Received Signal Strength (RSS) data or location data from a GPS device.

In [26], the associativity defined as the number of consecutive beacons that have been received from a specific link is used to evaluate the link stability. Though simple, b it does not provide much insight about the link stability, since the number of consecutive beacons can be affected by many network parameters and temporal variations of the nodal mobility.

In [27] - [29], predictions are done on the basis of the mobility models. In the mobility models, the nodes' motions are expressed by some specific statistical characters. They can only reflect a kind of the motions in realities [30], and the use of stability prediction-based routing algorithm is restricted.

In [31] - [33], authors use the changes of received power to estimate link stability. In [34], bridge nodes are used to measure link stability and it is considered that more bridge nodes between two neighbor nodes results in higher link stability.

A study on link stability prediction based on probabilistic models is proposed in [35], where the link stability is denoted as the conditional probability that a link remains connected after a specific time, given that it is currently connected.

III. STABILITY AND HOP COUNT BASED ALGORITHM FOR ROUTE COMPUTATION (SHARC)

Stability and Hop count based Algorithm for Route Computation (SHARC) using DSR as the basic routing protocol, is proposed in [36]. It is an approach for MANET routing based on stability and hop-count, where the residual lifetime of a link is considered as the stability metric. It is an enhancement to a hop-count based routing protocol (e.g. DSR or AODV), taking into account the expected residual lifetime as well as hop count of a route.

Initially, it is investigated how residual link lifetime is affected by parameters such as speed and mobility pattern. The residual link lifetime is a function of current link age, mobility speed and mobility pattern and does not vary monotonically with age. The intuitive idea such as older links are more stable is used in existing stability-based routing algorithms like Associativity Based Routing (ABR). It does not hold across a large spectrum of mobility speeds and models.

The stability of a path is calculated using a simple histogram based estimator.

A. Residual Lifetime

The collected link duration values from the former measurements are used to calculate the residual link lifetime. The average residual link lifetime is based on the number of links, link duration and the current link age.

B. Link Stability Estimator

To distribute stability information, the route-request packet of DSR is changed to carry residual lifetime information. Each node stores the link duration values of its neighbors. By collecting this information and aggregating them into bins of 10s, each node maintains an estimate of the residual lifetime distribution using the samples collected so far and equation (1).

During the initial period when the number of link duration samples collected is low, it is likely that a newer link will be chosen.

Every intermediate node on receiving the request packet includes the residual lifetime value in the route request message. The path structure is changed by associating every path with an additional stability value. The stability value of the path is the sum of all the residual lifetime divided by the length of the path. The route selection mechanism is incorporated in all the nodes.

Typically, the stability value of a particular link is calculated based on the most recent history, starting from the most recent link establishment. In the link estimator, the most recent link behavior along with the connectivity history of all neighboring nodes is considered. This helps in having a better understanding of the environment in which the node operates, making the estimates more accurate.

C. Route Selection Algorithm

The route selection mechanism assumes that routes are stored in the cache. The algorithm tries to find the most stable route among all shortest hop routes. The algorithm can be easily extended to the case where the most stable route among all routes with hop-count not more than ‘N’ hops longer than the minimum hop route, where $N \geqslant 0$, are chosen.

SHARC attempts to find a route based on path length and path stability. Link stability prediction is difficult and inexact. Finding a shortest path is precise. There may be more than one shortest path. Hence, a good approach is to use the shortest path algorithm as the initial filter to narrow down the route selections and then use path stability, a less robust indicator, to choose the best route among the available routes.

IV. PREDICTION BASED LINK STABILITY SCHEME (PLSS)

In a MANET, packet losses occur often when the nodes move out of range or the nodesdo not have path and link stability or neighbor node stability.

Prediction based Link Stability Scheme (PLSS) is proposed [37] to make a balance between stability of path, link, neighbor node and total mobile nodes to extend the network lifetime. The main of aim is to reduce the packet loss and provide better stability using the stability model.

The scheme consists of four phases like determination of stability of neighbor node, link, path, total mobile nodes and prediction of total network lifetime. It involves 4 steps.

- Finding the stability of neighbor nodes.
- Computation of the path from source to destination.
- Calculation of mobile node stability.
- Prediction of the network lifetime for a particular path.

PLSS is a prediction based stability scheme which attains stability in link, path and neighbor nodes. In the first phase of the scheme, stability of the neighbor nodes is achieved using mobility and stability of paths. In the second phase, stability of path is achieved. It uses three factors called mobility factor, link stability, link loss to favor packet forwarding by maintaining stability for each path. In the third phase, stability of total mobile nodes is reached using the threshold signal strength value. In the fourth phase, the network lifetime of the whole network is predicted.

Stability is the quality which asserts the network environment’s consistency. In MANET, nodes move from one place to another with a certain pause-time. Stability is an important parameter in such an environment.

There are two types of stabilities namely, neighbor stability and path stability. Neighbor Stability gives an idea of the neighbor’s consistency in the network while path stability gives an idea of the path’s consistency from a source node to destination. Neighbor stability aids in finding out the stable neighbor being used as a next hop node. Path stability helps in using a stable path for sending packets.

A. Stability of Neighbor Nodes

Mobility and link loss are the parameters taken into consideration of neighbor nodes stability. The node link loss can be measured by using Signal to Noise Ratio (SNR).

V. PROBABILISTIC PREDICTION COEFFICIENT BASED LINK STABILITY SCHEME (PPCLSS)

In the proposed PPCLSS approach, three steps are involved to obtain the probabilistic prediction coefficient. The coefficient determines the link stability for reliable data delivery in the entire network.

The three steps incorporated in the distributed approach for determining the link stability are

- Estimation of neighborhood stability based on Residual Energy (RE).
- Estimation of neighbor stability based on link loss.
- Manipulation of lifetime of mobile node.

A. Estimation of neighborhood stability based on Energy

Let E_i^{TOT} be the total energy of a mobile node 'i', RE_i and $PACK_i^{NO}$ denotes the Residual Energy and the number of packets relayed by node 'i'. Let E_{REQ} be the maximum energy required for transmitting a packet and E_i^{UTIL} be the energy utilized by a node in the path between the source and the destination. Then,

$$E_i^{UTIL} = \frac{RE_i - E_{REQ} \text{ X } PACK_i^{NO}}{E_i^{TOT}} \quad (1)$$

B. Estimation of neighbor stability based on link loss

The link loss ($LINK_{LOSS}$) is measured based on Signal to Noise Ratio (SNR) determined from Bit Error Ratio (BER).

$$LINK_{LOSS} = \frac{PACK_i^{NO}}{D^2 \text{ X } K} \quad (2)$$

where 'D' is the average distance between two mobile nodes and 'K' is the mobility proportion.

In ideal condition, i.e., when movement is almost constant (K=1) then,

$$LINK_{LOSS} = \frac{PACK_i^{NO}}{D^2} \quad (3)$$

C. Manipulation of lifetime of mobile node

The lifetime of path $PATH_{LIFE}$ is defined as

$$PATH_{LIFE} = \sum_{i=1}^{n} COST_{i,j} \quad (4)$$

where $COST_{i,j}$ is the cost between two mobile nodes and 'n' is the number of mobile nodes in the path. The average lifetime of the path is given by

$$PATH_{LIFE}^{AVG} = \frac{PATH_{LIFE}^{MIN}}{PATH_{LIFE}} \quad (5)$$

where $PATH_{LIFE}^{MIN}$ indicates the minimum lifetime of the path.

Therefore, the overall path stability of the route PS_{ROUTE} manipulated as the weighted sum of E_i^{UTIL}, $LINK_{LOSS}$ and $PATH_{LIFE}^{AVG}$ is given by equations (1), (2) and (5).

$$PS_{ROUTE} = \alpha . E_i^{UTIL} + \beta . LINK_{LOSS} + \gamma . PATH_{LIFE}^{AVG} \quad (6)$$

If the value of PS_{ROUTE} is less than 0.4, then alternate route discovery is enabled. Else, normal routing takes place. The maximum energy needed for transmitting a packet along with the total number of packets is considered and the Residual Energy (RE) of the mobile node is reduced.

D. Algorithm 1: Determining the link strength

The algorithm for determining the strength of a link is described. To estimate the link stability in a network, factors such as neighborhood stability based on energy, link loss and lifetime of mobile node should be taken into consideration.

NOTATIONS

RE_i - Residual energy of a mobile node

$PACK_i^{NO}$ - Number of packets forwarded by a mobile node

E_{REQ} - Maximum energy needed for transmitting a single packet

E_i^{UTIL} - Cumulative energy utilized by the nodes in the routing path

E_i^{TOT} - The total energy of a mobile node

$LINK_{LOSS}$ - Link loss estimate based on bit error rate

D - Average mobility distance

K - Mobility rate proportion (K=1)

$PATH_{LIFE}$ - Lifetime of the routing path

$PATH_{LIFE}^{MIN}$ - Minimum lifetime of the routing path

$PATH_{LIFE}^{AVG}$ - Lifetime of mobile nodes

n - Number of mobile nodes

For each $i = 1$ *to* n *do*

Compute:

Energy $E_i^{UTIL} = \frac{RE_i - E_{REQ} \text{ X } PACK_i^{NO}}{E_i^{TOT}}$

Link loss $LINK_{LOSS} = \frac{PACK_i^{NO}}{D^2}$ *(K=1)*

Life time of a node $PATH_{LIFE}^{AVG} = \frac{PATH_{LIFE}^{MIN}}{PATH_{LIFE}}$

Path stability of the route

$PS_{ROUTE} = \alpha . E_i^{UTIL} + \beta . LINK_{LOSS} + \gamma . PATH_{LIFE}^{AVG}$

If ($PS_{ROUTE} < PS_{THRESHOLD}$)

Call Root node_mitigation ( )

Else

Perform Normal routing

End

E. Algorithm 2: Electing a mobile node as the new rendezvous point node

Algorithm 2 elects a mobile as the new root node of the shared multicast tree, when the value of $PS_{ROUTE} < PS_{THRESHOLD}$. Each node present at one hop distance is analyzed. If the eligibility factor of the current root node is less than the newly elected node and radius of one hop neighbor, then the new mobile node is elected as the new rendezvous point.

NOTATIONS

QF - Qualifying Factor

ULINK - Unstable Link

$1HN_i$ -1-HopNeighbor node of 'i'

R_i - Radius of a node 'i'

If ($PS_{ROUTE} < PS_{THRESHOLD}$)

Begin

For each 1-hopnodes from current node do

$QF = \frac{E_i^{UTIL}}{RE_i}$

If ($QF_m > QF_{ULINK}$)

Select the m^{th} *node*

Else

Calculate radius of the one hop neighbor from the ULINK

If ($R_{1HN_i} < (\frac{R_i}{2})$)

Mobile node 'i' is elected as the new rendezvous point

else

Mobile node 'i' is isolated from the cluster

End.

Finally, if a mobile node is not elected as a leader node, network should be reconfigured.

VI. RESULTS AND DISCUSSION

The system is simulated using ns2. The simulation parameters are listed in Table 1. The results are analyzed by varying the number of mobile nodes and comparing it with LAER.

TABLE I. SIMULATION PARAMETERS

Parameters	Values
Area of Simulation	500 x 500
Number of nodes	20
Routing protocol	AODV
MAC	802.11
Antenna Model	Omni-directional
Transmission speed	1.2Mbps
Bandwidth	20MB
RE Threshold (τ)	0.5 J

The Packet Delivery Ratio (PDR) of SHARC is 8.37% less when compared to LAER. Similarly, the PDR of PLSS and PPCLSS are 4.49% and 13.20% more than that of LAERrespectively (Fig. 2).

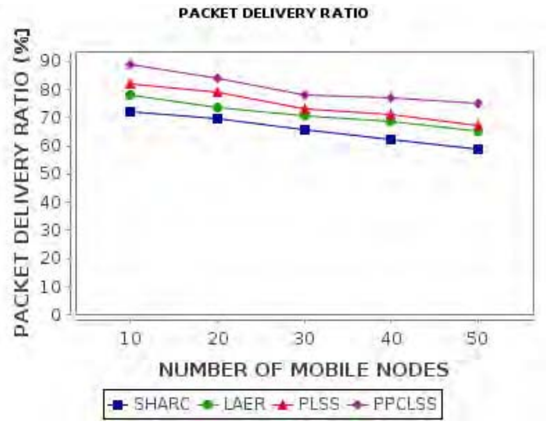

Figure 2. Packet Delivery Ratio based on number of mobile nodes

The Throughput of LAER is 9.51% more than SHARC, while it is 7.99% and 18.40% less than that of PLSS and PPCLSS respectively (Fig. 3).

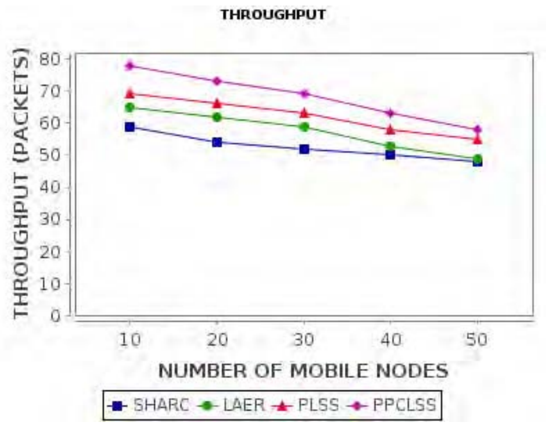

Figure 3. Throughput based on number of mobile nodes

The Control overhead of SHARC is 10.09% more when compared to LAER, while the Control overheads of PLSS and PPCLSS are 12.55% and 28.77% less in contrast to LAER respectively (Fig. 4).

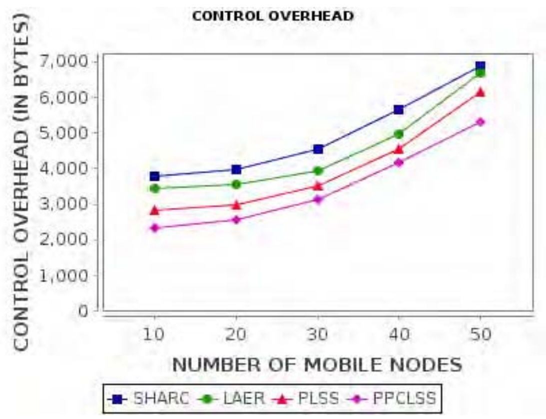

Figure 4. Control Overhead based on number of mobile nodes

The total overhead of LAER is 26.86% less when compared to LAER, while it is 8.42% and 32.36% more when compared to PLSS and PPCLSS respectively (Fig. 5).

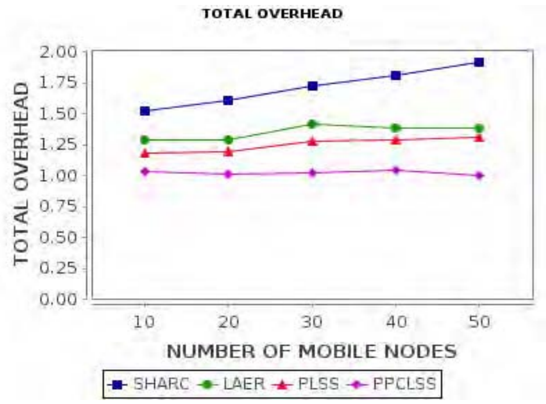

Figure 5. Total Overhead based on number of mobile nodes

The results are analyzed by varying the number of malicious nodes and comparing it with LAER. The Packet Delivery Ratio (PDR) of SHARC is 9.54% less when compared to LAER and 6.97% and 17.42% more in contrast to LAER respectively (Fig. 6).

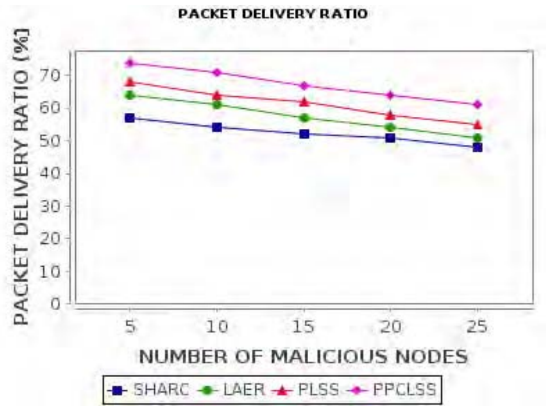

Figure 6. Packet Delivery Ratio based on number of malicious nodes

The Throughput of SHARC is 4.78% less when compared to LAER, while it is 5.61% and 12.28% less when compared to PLSS and PPCLSS respectively (Fig. 7).

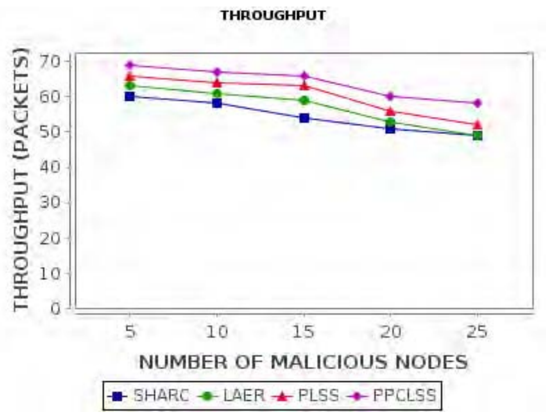

Figure 7. Throughput based on number of malicious nodes

The Control overhead of SHARC is 11.66% more than LAER, while the Control overheads of PLSS and PPCLSS are 20.1% and 53.91% less when compared to LAER (Fig. 8).

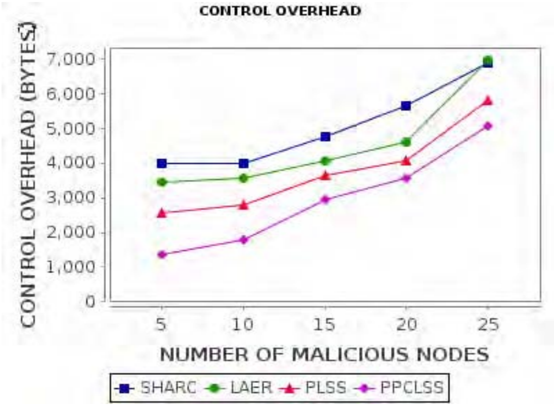

Figure 8. Control Overhead based on number of malicious nodes

The Total overhead of LAER is 8.85% less when compared to SHARC, while it is 7.26% and 18.49% less in contrast to LAER (Fig. 9).

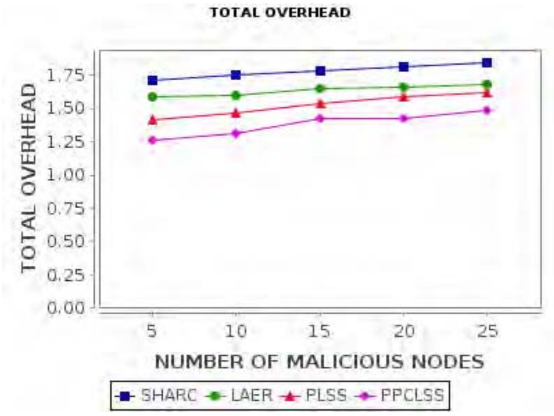

Figure 9. Total Overhead based on number of malicious nodes

VII. CONCLUSION

A scheme that prolongs the lifetime of a path by ensuring the stability of links is proposed. It considers the energy utilized for transmission of a packet and the average path lifetime. The performance of the proposed scheme, Probabilistic Prediction Coefficient Link Stability Scheme (PPCLSS) based routing is compared with the existing schemes like SHARC, LAER and PLSS. It is obvious that the scheme outperforms the schemes taken for assessment.

REFERENCES

[1] Taneja,S., & Kush, A.,"A Survey of routing protocols in mobile ad hoc networks", International Journal of Innovation Management and Technology, vol. 1, no. 3, pp. 2010 - 0248, 2010.

[2] Lokulwar, P. P., & Pandey, Y., "A Survey paper on Secure AODV protocol in MANAET using RSA algorithm and Diffie-hellman algorithm", International Journal of Scientific & Engineering Research, vol. 4, 2013.

[3] Kannhavong, B., Nakayama, H., Nemoto, Y., Kato, N., & Jamalipour., "A survey of routing attacks in mobile ad hoc networks", IEEE Wireless communications, vol. 14, no. 5, pp. 85 - 91, 2007.

[4] Singal, G., Laxmi, V., Gaur, M. S., & Lal, C., "LSMRP: Link stability based multicast routing protocol in MANETs", Proc. IEEE 7th International Conference on Contemporary Computing (IC3), pp. 254 - 259, 2014.

[5] Hu, X., Wang, J., & Wang, C., "Link stability prediction and its application to routing in mobile ad hoc networks", Proc. IEEE 2nd International Conference on Power Electronics and Intelligent Transportation System (PEITS), vol. 1, pp. 141 - 144, 2009.

[6] Wang, S., Song, Q., Feng, J., & Wang, X., "Predicting the link stability based on link connectivity changes in mobile ad hoc networks", Proc. IEEE International Conference on Wireless Communications, Networking and Information Security (WCNIS), pp. 409 - 414, 2010.

[7] Lim, G., Shin, K., Lee, S., Yoon, H., & Ma, J. S., "Link stability and route lifetime in ad-hoc wireless networks", Proc. International Conference on IEEE Parallel Processing Workshops, pp. 116 - 123, 2002.

[8] Meghanathan, N., "Stability-energy consumption trade-off among mobile ad hoc network routing protocols", Proc. 3rd International Conference (ICWMC) on Wireless and Mobile Communications, pp. 9, 2007.

[9] Maleki, M., Dantu, K., & Pedram, M., "Lifetime prediction routing in mobile ad hoc networks", IEEE Wireless Communications and Networking (WCNC), vol. 2, pp. 1185 - 1190, 2003.

[10] Toh, C. K., "Associativity -based routing for ad hoc mobile networks", Wireless Personal Communications", vol. 4, no. 2, pp. 103 - 139, 1997.

[11] Guerriero, F., De Rango, F., Marano, S., & Bruno, E., "A biobjective optimization model for routing in mobile ad hoc networks", Applied Mathematical Modelling, vol. 33, no. 3, pp. 1493 - 1512, 2009.

[12] Kyoung-Jin, K. I. M., "Power-efficient reliable routing protocol for mobile ad-hoc networks", IEICE transactions on communications, vol. 88, no. 12, pp. 4588 - 4597, 2005.

[13] Hou, Y. T., Shi, Y., Pan, J., & Midkiff, S. F., "Maximizing the lifetime of wireless sensor networks through optimal single-session flow routing", IEEE Transactions on Mobile Computing, vol. 5, no. 9, pp. 1255 - 1266, 2006.

[14] De Rango, F., Guerriero, F., Marano, S., & Bruno, E., "A multi-objective approach for energy consumption and link stability issues in ad hoc networks", IEEE Communications Letters, vol. 10, no. 1, pp. 28 - 30, 2006.

[15] De Rango, F., Guerriero, F., & Fazio, P., "Link-stability and energy aware routing protocol in distributed wireless networks", IEEE Transactions on Parallel and Distributed Systems, vol. 23, no. 4, pp. 713 - 726, 2012.

[16] Priya, M. D., &Valarmathi, M. L., "A cross-layered path stability based routing protocol for WiMax Networks", American Journal of Applied Sciences, vol. 10, no. 11, pp. 1325, 2013.

[17] Lee, S. J., Su, W., &Gerla, M., "On-demand multicast routing protocol in multihop wireless mobile networks", Mobile Networks and Applications, vol. 7, no. 6, pp. 441 - 453, 2002.

[18] Oh, S. Y., Park, J. S., & Gerla, M., "E-ODMRP: enhanced ODMRP with motion adaptive refresh", Journal of Parallel and Distributed Computing, vol. 68, no. 8, pp. 1044 - 1053, 2008.

[19] Su, W., Lee, S. J., & Gerla, M., "Mobility prediction in wireless networks", Proc. IEEE 21st Century Military Communications Conference (MILCOM), vol. 1, pp. 491 - 495, 2000.

[20] Tan, C., Chen, S., & Gong, X., "Steady routing protocol with prediction in mobile Ad Hoc networks", Minimicro systems-shenyang, vol. 28, no. 1, pp. 9, 2007.

[21] Lian, J., Li, L., & Zhu, X., "A multi-constraint QoS routing protocol with route-request selection based on mobile predicting in MANET", IEEE International Conference on Computational Intelligence and Security Workshops (CISW), pp. 342 - 345, 2007.

[22] Huang, J., & Liu, Y., "MOEAQ: A QoS-aware multicast routing algorithm for MANET", Expert Systems with Applications, vol. 37, no. 2, pp. 1391 - 1399, 2010.

[23] Wang, W., & Zhao, M., "Joint effects of radio channels and node mobility on link dynamics in wireless networks", Proc. 27th Conference on Computer Communications INFOCOM, 2008.

[24] Dube, R., Rais, C. D., Wang, K. Y., &Tripathi, S. K., "Signal stability-based adaptive routing (SSA) for ad hoc mobile networks", IEEE Personal Communications, vol. 4, no. 1, pp. 36 - 45, 1997.

[25] Jiang, S., He, D., & Rao, J., "A prediction-based link availability estimation for routing metrics in MANETs", IEEE Transactions on Networking, vol. 13, no. 6, pp. 1302 - 1312, 2005.

[26] Bamis, A., Boukerche, A., Chatzigiannakis, I., &Nikoletseas, S., "A mobility aware protocol synthesis for efficient routing in ad hoc mobile networks", Computer Networks, vol. 52, no. 1, pp. 130 - 154, 2008.

[27] Yu, M., Malvankar, A., Su, W., & Foo, S. Y., "A link availability-based QoS-aware routing protocol for mobile ad hoc sensor networks", Computer Communications, vol. 30, no. 18, pp. 3823 - 3831, 2007.

[28] Cho, S., & Hayes, J. P., "Impact of mobility on connection in ad hoc networks", Proc. IEEE Wireless Communications and Networking Conference, vol. 3, pp. 1650 - 1656, 2005.

[29] Xiao, B. L., Guo, W., Liu, J., & Zhu, S. L., "Pseudo gossip routing algorithm based link stability in mobile ad hoc networks", Journal on Communications, vol. 29, no. 6, pp. 26 - 33,2008.

[30] Camp, T., Boleng, J., & Davies, V., "A survey of mobility models for ad hoc network research", Wireless communications and mobile computing, vol. 2, no. 5, pp. 483 - 502, 2002.

[31] Agarwal, S., Ahuja, A., Singh, J.P., Shorey, R., "Route-lifetime assessment based routing (RABR) protocol for mobile ad-hoc networks", Proc. IEEE International Conference on Communications, vol. 3, pp. 1697 - 1701, 2000.

[32] Paul, K., Bandyopadhyay, S., Mukherjee, A., & Saha, D., "A stability-based distributed routing mechanism to support unicast and multicast routing in ad hoc wireless network", Computer Communications, vol. 24, no. 18, pp. 1828 - 1845, 2001.

[33] Li, H., Ting-Pei, H., Wei-Xia, Z., Shu-rong, L. I., & Zheng, Z. H. O. U., "Research of AODV routing protocol based on link availability prediction", In Journal on Communications, vol. 29, no. 7, pp. 118 - 123, 2008.

[34] Penz, S., "A DSR Extension for Connection Stability Assessment in Mobile Ad-Hoc Network", Proc. PerCom Workshops, pp. 509 - 513, 2007.

[35] McDonald, A. B., & Znati, T., "A path availability model for wireless ad-hoc networks", Proc. IEEE Wireless communications and networking conference (WCNC), pp. 35 - 40,1999.

[36] Sridhar, K. N., & Chan, M. C., "Stability and hop-count based approach for route computation in MANET", Proc. 14th IEEE International Conference on Computer Communications and Networks (ICCCN), pp. 25 - 31, 2015.

[37] Wang, S., Song, Q., Feng, J., & Wang, X., "Predicting the link stability based on link connectivity changes in mobile ad hoc networks", Proc. International Conference on IEEE Wireless Communications, Networking and Information Security (WCNIS), pp. 409 - 414, 2010.