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Research paper

Path Stability Prediction for Stable Routing using Markov Chain Model in MANETs

Calarany C[1*], Manoharan R[2]

[1, 2]Dept. of Computer Science and Engineering, Pondicherry Engineering College, Puducherry
**Corresponding Author E-mail: [1]ccalarany97@gmail.com.*

Abstract

The mobility factor and the energy level of a node during data transmission in MANET are considered to be the most important challenges amongst several other issues like link stability, security and QoS factors in the designing of routing protocols. Forecasting the path stability, leads to an effective and reliable communication between the nodes in a highly dynamic scenario. Subsequently, in most of the work metrics namely hop count and energy are considered for stable path selection and mobility is handled in few works. Therefore, in this paper a prediction model with bi-objective optimization using Active Interactive Neighbour Rate (AINR) and Energy (E) have been considered for stable path selection. Markov models are widely used for depicting random behaviour in several processes related with time series. However, this model has not been utilized for predicting the stable path in a highly mobile network, taking into consideration the issues of mobility and energy. Hence, in this work a new Path Stability Prediction model, using Markov chain namely PSPM has been proposed, using two metrics namely AINR and E. The proposed model is incorporated in a multipath routing protocol, which identifies the optimal path in terms of minimum AINR and minimum energy consumption, which has been evaluated using NS 2.35. From the simulation, it has been found that the new protocol shows enhancement in results than the existing protocols namely AODV and AOMDV, in terms of various parameters such as Packet Delivery Ratio, Throughput, End-to-End Delay, Energy consumption and Routing Overhead.

Keywords: *MANET, Path Stability, Energy, Markov chain, Active Interactive Rate, Path Reliability Factor.*

1. Introduction

Mobile Ad-hoc network (MANET) is an infrastructure less network with dynamic topology in which all the mobile nodes are in random motion. It is an unbiased system of mobile nodes which are connected by wireless links. MANETs are very much suitable in various environments where there is no fixed infra structure such as military, rescue operations, mining, video conferencing and emergency situations. There are many issues and challenges in MANET such as Link Stability, Energy, Node mobility, Trust, Fault Tolerance and Security.

Each node has a limited battery power, using which it is able to communicate with other nodes via wireless connections. In order to perform the data transmission, nodes along the path need sufficient battery power. There are various factors which affects the battery power of a node namely, transmission power, receiving power, number of neighbours, node density, etc. Hence, designing an energy efficient routing protocol is a challenging task [1]. Since, there is a limitation with regards to the range of transmission for communication, the mobility of the intermediate nodes must also be taken into account for the effectiveness. The high mobility of the node, in a dynamically changing topology, results in poor performance of routing protocolin MANET[2]. In an emergency situation such as in military barracks or at times of disasters, time taken for communication of the message plays a major role for determining the reliability of the path. Hence, it becomes necessary to predict the stability of the path, to transmit the data within a short duration of time.

The path selection in MANET can be implemented using single factor or multiple factors. When a single objective is used for path selection there is a chance of getting a biased output. In most of the research works done,the path selection has been done using the metric hop count, in which the path with minimum number of hop count is selected [3]. In addition to this metric, several other metrics namely, mobility of the node, residual energy of the node, bandwidth availability, etc. are analysed for finding an effective solution in case of single objective optimization problem. The drawback with the hop count metric is, buffer overhead, that results in the maintenance of a long queue for storing the neighbourhood nodes. Hence, a new metric namely Active Interactive Neighbour Rate [4] has been used as a replacement of the hop count metric. Active Encounter Rate is the number of new active neighbours encountered at an interval of time. When AINR of a node is lesser, it indicates that the lesser number of control packets will be generated and thereby makes this metric useful for mobility control in MANET. In case of bi-objective optimization problem, the optimal path is selected by using two metrics such as number of hops and energy or other combinations of hop count [5]. In our work, the bi-objective optimization problem has been tackled using AINR and E metrics. Prediction is the process of forecasting the future value based on the past and present data. Prediction models find their applications in numerous zones namely prediction of price indexes in stock markets, prediction of exchange rates between foreign currencies, prediction of increase in population, prediction of safety measures in road traffic, prediction of accidents and so on.

Prediction model grounded on time is known as 'Time Series Prediction Model' (TSPM). Time series prediction is defined as a

process in which the forthcoming values of a scheme is predicted from the information collected from the past events and current events. A mathematical model defined earlier is used to provide precise predictions. Here, a sequence of data points is considered at uniform time intervals. Two types of time series predictions are available: First type is model based and the second type is data based prediction models. The quantitative models like system dynamics were used in former models where the behaviour of the system was being predicted by means of its inner structure and mechanisms. The mathematical model is used in the latter case where the experimental data is being used as the source. A third type is also available known as hybrid time series predictions which is a combination of both the types. Intelligent approaches include various time series prediction models such as linear regression, Kalman filtering, fuzzy systems, artificial neural networks, evolutionary and genetic algorithms, Hidden Markov models and grey theory. Markov chain model is a stochastic model in which the present state depends upon its previous state.
There are two phases in the current work:

- In phase one, the bi-objective optimization problem, depicted as a stochastic multipath routing, is solved using two metrics AINR and E.
- In phase two, the salient features of Markov chain prediction models are used to predict the stable path, using transition probability of all the mobile nodes on the network.

Hence, an energy efficient and reliable multipath routing protocol has been proposed using Markov chain process taking measures to minimize the node mobility and energy. In this paper, section 2 throws light on the related work, section 3 is with regards to the discussion of the proposed model, section 4 discusses the results obtained and the evaluation summary and section 5 describes the conclusion and the enhancements to be carried out.

2. Related Work

In a self-organized dynamic ad hoc network, designing of the routing protocol for efficient data transmission is a challenging task. There are various issues in routing such as node mobility, energy, security, fault tolerance etc., and the following section provides a detailed study on optimization issues and the prediction models. In prediction models, various situations exist where in numerous time series are found to be interconnected i.e. time series elements of one can transit into another time series. Hence, a Markov chain forecast model may exercise such workings with the help of a transition probability matrix estimation, enabling a predictor to perform the prediction of entire set of the interconnected time series concurrently. Also, this model is supportive in accepting numerous prediction expectations and erections.
According to the study put forward in paper [4], the authors have proposed a novel metric known as 'Active Encounter Rate (AER)', which providesa count of new nodes that come across in an interval of time. For data transmission this metric is used as a replacement metric for hop count in case of the forward node selection. Instead of AER, the square of it i.e., 'AER^2' has been taken to minimize the least mean square error while predicting the node stability or node density in a network. Hence, the neighbour node selection was carried out by
considering the min(AER^2)of all nodes in the path. However, energy of the node and path stability were not considered in this work.
In paper [5] the authors propounded a prediction model to select an energy efficient, secured optimal path using a stochastic Markov chain process. Using multipath routing it is possible to achieve the maintenance in the load balancing of the data flow among the nodes by selecting various paths in each time slot, based on energy factor. The protocol created was implemented by modifying AOMDV protocol. Secured data transmission was possible due to the transmission of packets through various reliable paths based on Markov chain prediction. However, the node mobility has not been taken into account here.
In paper [6] the authors attempted a technique for predicting the pattern of mobility at varying time intervals of the nodes in MANET based on the previous location, speed, direction of movement of the nodes. This article used Random Way Point model and while predicting the mobility the hop count related issues were not counted. The energy factor was also not discussed.
In paper [7] the authors proposed a protocol namely 'Mobility Prediction with link stability based multicast routing protocol in MANETSs (MORALISm)' to predict the node stability based on link duration. Signal strength variation was used to predict if the direction the node traverses, is either towards the assessed node or away from it. The links were selected based on maximum duration. The node's energy was not considered here.
In paper[8] the authors came up with 'Prediction method based on Link Stability Scheme (PLSS)' in which there are four phases, determination of stability of the neighbour node, stability of the link, stability of the path, total number of all mobile nodes and the lifetime of the network. PLSS algorithm shows better performance based on various performance metrics than the existing LAER scheme. However, the energy factor was not taken into account here.
In paper [9] the authors planned protocol for routing mechanism namely 'Power Efficient Reliable Routing Protocol for Mobile Ad hoc Networks' for the selection of reliable path. There are three metrics used for path selection. First metric: Energy consumed for packet transmission. Second metric: Available energy of the node. Third metric: Factor denoting the path stability. Routing procedure is similar to the DSR protocol.
In paper [10] the authors considered two metrics namely, stability factor and energy factor and formulated the routing mechanism as a bi-objective mathematical model. In their work, protocol analysis in terms of performance metrics had not been performed.
In paper [11] the authors propounded a novel routing protocol namely 'Link Stability and Energy Aware Routing Protocol (LAER)'. The proposed algorithm was designed by using the bi-objective optimization model. In this model, first metric drain rate of the nodes and second metric stability of the link were the two metrics that has been considered for effective path selection. The protocols such as PERRA, GPSR and EGPSR were compared to analyse the performance of the LAER protocol. The author did not claim the path stability for packet routing in MANET and this work did not resolve issues that arise due to high mobility. The link duration in this paper yielded was longer than PERRA and E-GPSR because of maintenance of life time history of the links and thus resulted in poor performance.
In paper [12] the authors discovered a multipath routing protocol to save energy namely 'Fitness Function AOMDV (FF-AOMDV)'. In this protocol, AOMDV has been modified using fitness function. The source node uses three types of information for fitness function evaluation such as the energy level of every node in the network, the distance between the source and destination of all routes and the quantity of energy consumed during route discovery. The node mobility is not considered.
In paper [13] the authors propounded a protocol for routing mechanism called as 'BRSR_AOMDV' which involved a technique to deal with link stability and load balancing depend upon the strength of the signal and average queue length. The path selection was based on least queue size with high link stability. Various performance metrics namely packet delivery ratio, network life time, throughput were analysed and they proved that their protocol provided better results than AODV protocol. In this paper energy was not considered.
In paper [14] the authors proposed a Naïve based classification and Markov model to predict the mobility of the node using the mobility history of the traversal path of the nodes. In this paper both temporal and spatial information about the mobility have been used. In case when the mobility pattern was not available then prediction was based on Short Messaging Servicing'(SMS)'

and coordinates of the node based on geographical position. The node energy was not taken into account.

In paper [15] the authors predicted stability of the link using Markov Renewal Process(MRP) based on probabilistic model. In this model, metrics like transition probability distribution and the waiting time between consecutive events termed as 'Sojourn time' were used to find the link behaviour. The availability of the link was predicted to be between the time interval T and $T + t_0$. Unlike Markov chains which make use of transition probabilities alone to predict link state, MRP made use of state sojourn time for the prediction of link availability. The performance of MRP showed that link state prediction with high accuracy was possible, which in turn can lead to a better QoS. In this paper energy was not considered.

In paper [16] Semi-Markov model has been used to predict the mobility in the cellular networks. This model predicts the spatiotemporal mobility which is tied with stable state and proliferate analysis in the cellular networks. It has been found from the traces of a real network that it achieves an accuracy of 90% in prediction in the tentative assessment leveraging in the smartphone application. In this paper energy was not considered.

In paper [17] a scheme namely 'Mobility and Load aware Routing scheme(MLR)' based on Markovian decision process has been propounded to solve the problem of flooding by minimizing the messages rebroadcasted in the nodes which are slower in nature and also having lesser load. In this method, high speed nodes are not selected for data transmission and the loads are distributed among them to improve the performance of the scheme. The energy was not considered in this work.

In paper[18] the authors propounded a method for forecasting an optimal path using time series 'Autoregressive Integrated Moving Average model (ARIMA)'model and 'Multi Layer Perceptrons (MLP)' model. In this model neural network was used to forecast the optimal path. Different mobility models had been taken and implemented in AODV protocol for predicting the path length. It has been found that MLP based model forecasting results were better than ARIMA model. Energy was not considered.

In paper [19] the authors proposed the Prediction of link quality in routing algorithm in MANET. 'The Link Quality Evaluation (LQE)' has been done on Packet reception ratio. Two faults have been identified in this method. The first one was the lag of assessment and the second fault was unfairness in sampling. Hence, there was a hand off delay in routing protocols. In this paper, a grey prediction model has been proposed that predicts the neighbour link quality by Signal Noise Ratio (SNR). LQP is implemented in OLSR. However, the path stability of the node and energy are not quantified.

In paper [20] the authors propounded a novel forecasting model in the wireless sensor networks which relies upon 'Combined Grey model and Kalman Filter Data Aggregation (CoGKDA)'. Energy was saved in this prediction technique by lowering redundancy in transmission. A technique namely double-queue mechanism has been used to coordinate prediction of the data series of the sender node and the receiver node. This mechanism resulted in the reduction of the accumulative error of continuous predictions. However, the node mobility is not included in forecasting.

In paper[21]for the weighted delay prediction, length of the path and End-to-End delay had been used in regression analysis. Fuzzy time series had been used to represent the End-to-end delay between the source and the destination. Hence, with suitable weightage for two predictions, namely path length regression equation and fuzzy time series, End-to-Enddelay in the current path was found.

In paper [22] the authors proposed three grey models to predict various parameters like travel time, vehicle speed on freeways in road traffic. The forecasting for the models were 'Grey model (GM(1, 1))',' Enhanced Forecasting of Grey Model (EFGM)' and 'Grey Verhulst Model with Fourier Error correction (EFGVM)'. Two kinds of errors namely 'Root Mean Square Error (RMSE)' and 'Mean Average Percentage error were made use of in prediction. EFGVM provided the best accuracy compared to other protocols for abrupt change in the speed of the nodes. In this paper energy was not considered for prediction.

The main contributions of our work are listed as follows:

- In most of the works, it can be seen that hop count is used as primary metric in path selection. In our work, the buffer overhead that results due to the long queue maintenance of neighbour nodes is avoided by the choice of Active Interactive Neighbour Rate (AINR) metric.
- Subsequently, AINR is used in the evaluation of mobility and energy metrics for solving the bi-objective optimization problem.
- The salient features of Markov chain process have been incorporated for predicting the reliable path, with the minimum AINR and minimum drain node.

Hence, from the literature survey it has been explored that the drawbacks in case of hop count metric can be overcome by the introduction of AINR metric and in the following section a Markov chain model-based protocol has been proposed for the prediction of path stability in the ad-hoc environment. The optimal path selected consists of nodes with minimum AINR value indicating that the low mobility and minimum drain rate for all nodes along the selected path results in better performance of the network.

3. Proposed Routing Protocol

MANET is a highly dynamic infrastructure where the node mobility is a critical issue that affects the efficiency of the network. In bi-objective optimization problems a combination of any two related metrics is considered to find the optimal path. The proposed algorithm works in two phases namely:

- Determination of pare to solutions for the bi-objective optimization model in terms of two metrics mobility and drain rate coined using AINR.
- Implementation of an efficient routing mechanism based on the prediction of stable path using Markov chain prediction process.

3.1. Calculation of Path Reliability Estimation Factor (PRF)

In the proposed method, the PRF is attained by the weighted accretion method of two features that corresponds to the packet transmission capacity referred to as Path InteractiveNeighbor Rate (PINR) and energy factor of routing paths called as the aggregate energy drain rate of paths ($A_{Drain-rate}$)[23]

In order to estimate the Path Interactive Neighbor Rate (PINR), at first in each session, Active Interactive NeighborRate (AINR) of mobile nodes in each and every path is evaluated using equation (1) represented as the ratio of number of active interactions (En) to the duration of interactions (T)

$$AINR = \frac{|En|}{T} \quad (1)$$

Then the Path Interactive Rate (PINR) is computed through the determined AINR of the node and Mean Active Interaction of nodes in the paths (MAINR) established for routingusing equation (2)

$$PINR = \sum_{i=1}^{m}(AINRi - MAINR)^2 \quad (2)$$

In the computation of aggregate energy drain rate of paths ($A_{Drain-rate}$), First the energy drain of paths is determined based on the ratio of Energy threshold limit ($E_{\lim it}$) of each path to the number of hops (N_h) in each path based on equation (3). [23]

$$E_D = \frac{E_{\lim it}}{N_h} \tag{3}$$

The residual energy of paths (RE_{path}) is determined based on the ratio of Initial Energy available in the path (E_{init}) to the estimated energy drain of paths (E_D) using equation (4) [23]

$$RE_{ptth} = \frac{E_{init}}{E_D}$$

Then the aggregate energy drain rate of paths ($A_{Drain-rate}$) is determined through the difference between the initial energy possessed by each individual path ($E_{path-initial}$) and the residual energy of paths (RE_{path}) using Equation (5)[23]

$$A_{Drain-rate} = E_{path-initial} - RE_{path}$$

Finally, the PRF factor of each paths are calculated based on the aggregate weight of PINR and $A_{Drain-rate}$ based on Equation (6)

$$PRF = Wt1 * PINR + Wt2 * A_{Drain\text{-}rate} \tag{6}$$

Where, 'Wt1' and 'Wt2' corresponds tothe appropriateprecedence that ranges between 0 and 1.

3.2. Markov Chain based Accuracy Estimation of Path Stability for Routing.

Markov chain is a process performed in a random manner in which the state hinges upon only its preceding state and not on the other states. Let R= {R_1, R_2, …, Rn} be a set of states in the Markov chain. In general, each state represents one process. Any of these states can be the starting point for the process. Subsequently, the successive movements between the states are depicted as steps. Decision maker has the option of moving from one state to another based on any operation that is accessible from that node. Hence, when there is movement from state R_l to R_m, the response of the process is denoted by the probability P_{lm} known as transition probability. Henceforth, the decision maker is being provided with a recompense (R_l, Rm, r). In Markov chain process, for the states in R it is required that a probability distribution has to be set at the initial stage. In this work, each path is represented as a state.The optimal path selection is possible by selecting the path in terms of max(min (residual energy of nodes)) among all the paths. The metric minimum residual energy factor of the path is denoted by 'min-prf'.

3.2.1 Stochastic multipath routing using Markov chain

It is a mechanism in whichduring a particular time intervalthe selection of the next path for packet transmission is based upon the value available in the 'Transition Probability Matrix(TPM)'. The difficulty lies infinding the appropriate routing policies for the identification of a path in terms of energy efficiency and stability.

The Markov chain is initiallyused to formulate Markov transition matrices that identify the transition behavior grounded on the energy factor and stability factor of all the nodes across various paths. Let R be the number of paths representing thestates as R ={R_1,R_2,…,R_{np}}. Hence, the order of the Markov transition matrix is'R x R'. i.e. to represent each state as path the 'min-prf' of the path is taken which is the minimum residual energy of the node among all the nodes in the path. Each state of the transition matrix represents the path from sender node to the receiver node asdepicted in Figure1. In the scenario, when total number of paths formulated between source and destination are enormous, the paths with highest energy and stability factor based on 'PRF' are selected with a threshold value for Markov chain. During the first-time slot the data transmission will be through the selected path having maximum of initial probability distribution.The selection of the path from second time slot will be based on Max-Min path selection technique, i.e. Among all the nodes the node with AINR based min-prf will be the minimum energy node of the path which is the first node that will be expired.Hence to represent each path the node which is having the minimum residual energy will be taken as the residual energy of the path.

Let E_{resn}= Residual energy of a particular node in the path

E_{initn} = Initial energy of a particular node in the path (4)

$A_{drainraten}$ = Drain rate of a particular node in the path

For each node in the path, the min. energy factor is estimated using the formula (7)

$$min\text{-}prf_n = E_{resn} / (E_{initn} * AINR) \tag{7}$$

where E_{resn}= E_{initn}-$A_{drainraten}$

Calculate *min-prf* for each node of each pathand select the node with minimum energy factor for each pathwhich is considered as the minimum energy factor of that path. (5)

Let R = {R_1, R_2, R_3,.., R_{np}} be the no. of paths representing each state in the Markov chain and

$\min\_prf_R = \{\min\_prf_{R_1}, \min\_prf_{R_2}, \min\_prf_{R_3}, \dots, \min\_prf_{R_{np}}\}$

be the set of minimum energy factor of Np number of paths.Let K_{R_i} be the probability distribution of the path Ri set initially. To calculate K_{R_i}

$$K_{R_i} = \frac{\min\_prf_{R_i}}{\sum_{k=1}^{np} \min\_prf_{R_k}} \tag{8}$$

The initial probability distribution obtained for all paths is givenby equation(9)

$$K_R = \{K_{R1}, K_{R2}, K_{R3}, \dots, K_{np}\} \tag{9}$$

During the firsttime slot the optimal path selection is doneby using equation (10)

$$OP = \max (K_{R1}, K_{R2}, K_{R3}, \dots, K_{np}) \tag{10}$$

From the second time slotonwards to estimate the transition from one path to another, the formulae used are

$$P_{Ri\,Rj} = \begin{cases} \frac{|\min\_prf_{R_i} - \min\_prf_{R_j}|^{\beta}}{\sum_{np} |\min\_prf_{R_i} - \min\_prf_{R_j}|} & Ri \neq Rj,\ min\_prfRi > min\_prfRj \\ \frac{|\min\_prf_{R_i} - \min\_prf_{R_j}|}{\sum_{np} |\min\_prf_{R_i} - \min\_prf_{R_j}|} & Ri \neq Rj,\ min\_prfRi > min\_prfRj \\ 1 - \sum_{o \epsilon np} P_{RiRo} & Ri = Rj, Ri \neq R0 \end{cases} \tag{11}$$

Where β is an exponent used to avoid the selection of path from lower energy to higher energy path and β >=2. In this model β has been assigned a value of2.

Let K_R be the initial probability distribution of the selected paths and P be the TPM of each Markov chain. Selection of the optimal path for data transmission in each time slot using the Markov chain is given by

$$K_R' = K_R \times P_{RiRj} \tag{12}$$

The path with max. probability will be the optimal path for data transmission in the next time slot.

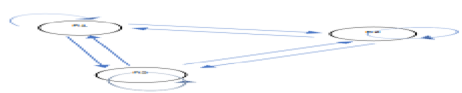

Fig. 1: Markov Chain Model for 3 paths

Algorithm 1- Improved Path Stability Prediction using Markov Technique

Sr -Source node
Ds-Destination node
Np- Number of stable paths between source Sr and destination Ds.
AINR-Active interaction neighbor rate
MAINR – Mean Active interaction neighbor rate
PINR – Path interactive neighbor rate
E_n- Number of active interactions
E_{init}- Initial energy possessed by mobile nodes of the path
E_{limit} - Maximum energy possessed by mobile nodes of the path
RE_{path}-Residual energy of the paths
E_{Resn}- Residual energy of a particular node
E_{initn} - Initial energy ofa particular node
N_h-Number of hops of the path
Wt1, Wt1-Weights
PRF- Path Reliability Estimation Factor
L – No. of slots
T-time of interactions
min-prf_n-The node with minimum energy in the path

1. Start
2. For all paths from Sr to Ds
3. For sessions from 1 to 'S' do / * Path Discovery */
4. Calculate for each mobile node Active Interactive Neighbor Rate $AINR = \frac{|En|}{T}$
5. Calculate energy drain of the path $E_D = \frac{E_{\lim it}}{N_h}$
6. Using energy drain of paths calculate residual energy of paths using $RE_{path} = \frac{E_{init}}{E_D}$
7. Calculate Path Interactive Neighbour Rate (PINR) based on AINR of each node and mean AINR of all the nodes in the path

$$PINR = \sum_{i=1}^{m} (AINR_i - MAINR)^2$$

8. Compute aggregate drain rate of energy in paths based on $A_{Drain-rate} = E_{initial-path} - RE_{path}$
9. Calculate Path reliability estimated factor, *PRF = Wt1 * PINR + Wt2 * A* $_{Drain\text{-}rate}$
10. Predict precise path stability of the paths using PRF of paths with a threshold value

. Choose that path as *Np = Sr-> Ds*

/* LetN_P= {R_1, R_2, R_3,…,R_{np}} be the set of paths based on PRF value */
/*Selection of the path for data transmission in each routing stage */

11. Calculate the energy factor for each node of the path using the formula

min-prf_n= E_{Resn} / (E_{initn} * AINR)
/* Minimum energy factor of a node in a path is taken as the minimum energy factor of that path */

12. Among all the nodes in a path select the node with minimum energy factor for a path 'i' as

min-prf_{Ri} = min(min-$prfn_1$,min-$prfn_2$,…min-$prfn_h$).

13. Repeat steps 11 and 12 to select the node with minimum energy factor for each path.

Let $\{\min\_prf_{R_1}, \min\_prf_{R_2}, \min\_prf_{R_3}, \ldots, \min\_prf_{R_{np}}\}$ be the set of minimum energy factor of Np number of paths.

14. Compute initial probability distribution K_{R_i} of the path Ri using the formula

$$K_{R_i} = \frac{\min\_prf_{R_i}}{\sum_{k=1}^{np} \min\_prf_{R_k}}$$

15. Compute initial probability distribution of all the paths $K_R = \{K_{R1}, K_{R2}, K_{R3}, \ldots, K_{np}\}$
16. Compute initial optimal path *OP= max* $(K_{R1}, K_{R2}, K_{R3}, \ldots, K_{np})$
17. Send the data packets through the path OP.

/* Path stability Prediction using Markov chain */

18. For slots from 2 to L
19. Calculate the minimum energy factor of each path using steps 11 to 13.

Let $\{\min\_prf_{R_1}, \min\_prf_{R_2}, \min\_prf_{R_3}, \ldots, \min\_prf_{R_{np}}\}$ be the set of minimum energy factor of Np number of paths.

20. Calculate TPMof the Markov chain using $P_{RiRj}$from equation (11)
21. Compute the transition probability distribution of the paths $K_R' = K_R \times P_{RiRj}$
22. Transmit the data packets through optimal path which is max(K_R')of all the paths.
23. $K_R = K_R'$
24. End for.
25. End for.
26. End for.
27. End.

In this paper there are two contributions. First, we have proposed a bi-objective optimization model for the determination of stable path from a specific source to a destination has been proposed. The two parameters are path stability and the residual energy of the nodes in terms of Active Interactive Neighbour Rate of the nodes in the path. Secondly a prediction for highly stable path based on Markov chain prediction model using TPM has been proposed.

4. Simulation Results and Evaluation

The proposed protocol is evaluated by comparing with the bench mark protocol namely AODV and a multipath protocol namely AOMDV [24]protocol. The simulation has been carried out in NS2-2.35.The number of nodes has been taken in the range from 20 to 100 for analysing the performance under the metrics given below. In the experimental run, the 'Constant Bit Rate (CBR)' and 'FTP' are used as a traffic source. The mobile nodes are placed randomly in a 1000*1000m network area. Since the nodes are moving rapidly the network topology changes randomly. The initial energy of the node is set to 100 joules and the range of transmission was set to 250 m. The parameters related with the simulation are shown inTable1.

Table 1: Simulation parameters

Parameters	Values
Network nodes	100
Density of nodes	15 square meters
Link Selection interval	8 seconds
Transmission Range	250 meters
CBR data rate	24 Mbps
Interval of hello packets	1 second
Mobility speed	5-35 m/sec
Traffic type	CBR
Radio type	802.11 a/g

5. Performance Metrics

The performance metrics used in the simulation experiments to measure the protocol efficiency are as follows.

1. Packet Delivery Ratio (PDR) Metric: It is defined as the "ratio of the data packets that were delivered to the destination node to the data packets that were generated by the source". This metric measures the quality of a routing protocol. If the PDR value is higher, then the performance of the routing protocol is also higher. Since multi path selection is based on nodes with minimum energy consumption and lesser mobility i.e. minimum AINR and data transfer is based on the Markov chain prediction before the path expires during each time slot, packet delivery ratio is higher than the other protocols. From the figure 2.a it has been found that the packet delivery ratio is increased by 19% and 10% than AODV and AOMDV protocol.

2. Throughput Metric: "Throughput is known as the number of bits that the destination has successfully received expressed in kilobits per second (Kbps)". The routing protocol's efficiency is measured by throughput a in terms of data packets received by the destination. Since the multiple path selection is based on bi-objectives and prediction is based on Markov chain, the throughput has been increased than the protocols used for comparison. With reference to the figures 2.b it has been found that throughput is increased by 25% and 12% than AODV and AOMDV protocol.

3. End-to-End delay Metric: "End-to-End delay refers to the average time taken by data packets in successfully transmitting messages across the network from source to destination". This metric is a combination of related delays such as delay during the queuing process, propagation delay, retransmission delay at the MAC layer and delay during buffering operation. In AODV protocol the new path will be discovered only whenever there is a path failure. Hence more end-to-end delay. In AOMDV protocol even though multiple paths are generated energy and mobility of the nodes are not taken into account. Hence in the proposed protocol, there is a reduction in the End-to-End delay than the other two protocols. Figure 2.c shows that average End-to-End delay is decreased by 28 % and 12% than AODV and AOMDV protocol.

4. Energy Consumption Metric: "Energy consumption refers to the amount of energy that is spent by the network nodes within the simulation time. This is obtained by calculating each node's energy level at the end of the simulation, factoring in the initial energy of each one". In the proposed protocol, since the path selection for data transmission is based on the nodes with minimum number of neighbours, the energy consumption is lesser than the other protocols. With reference to the figures 2.d it is found that energy consumption is decreased by 33% and 14% than AODV and AOMDV protocol.

5. Total Routing Overhead Metric:" It is defined as the ratio of number of packets required for end-to-end communication between source to destination and actual number of packets received by the destination". It is also noted that in terms of congestion, as our protocol has been given preference for the node with less AINR, it reduces the interaction flow between the nodes resulting in a lesser number of control packets than AODV and AOMDV protocols. Hence from figure 2.e it has been found that the Routing overhead is decreased by 49% and 26%than AODV and AOMDV protocol.

Hence the performance of the proposed protocol PSPM was compared with AODV and AOMDV protocol and it is identified that the performance of protocol based on Energy and AINR is significantly better than AODV and AOMDV in terms of the performance metrics such as Packet Delivery Ratio, Throughput, Energy consumption, End-to-End delay and Routing overhead.

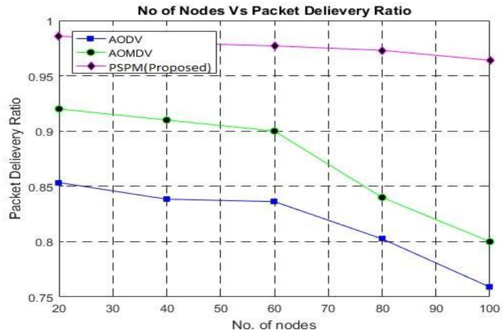

Fig. 2a: Number of Nodes Vs Packet Delivery Ratio

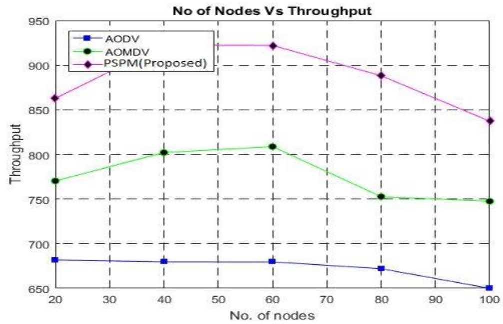

Fig. 2b: Number of Nodes Vs Throughput

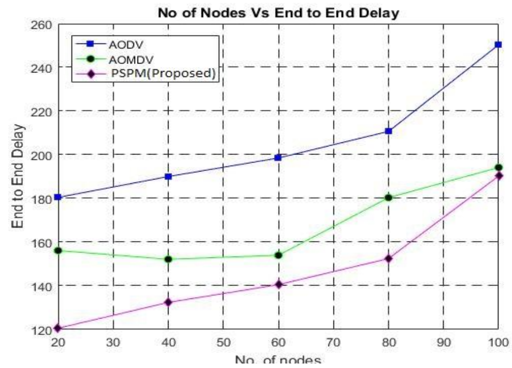

Fig. 2c: Number of Nodes Vs End-to-End Delay

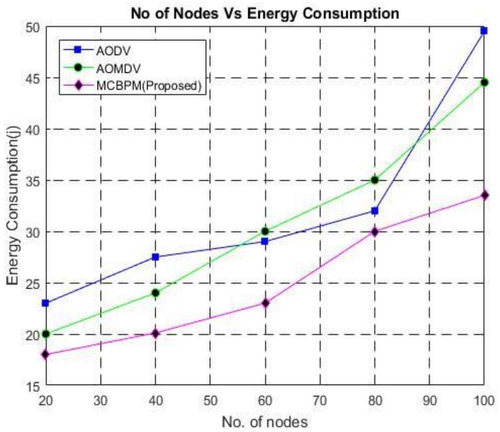

Fig. 2d: Number of Nodes Vs Energy Consumption

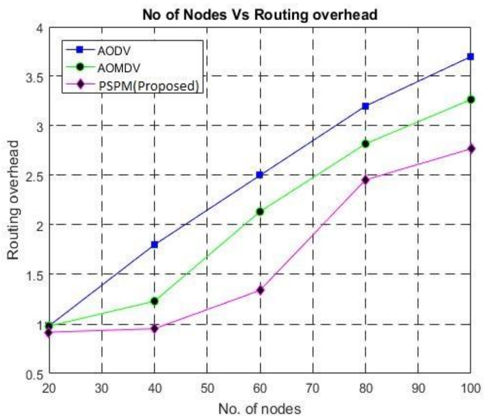

Fig. 2e: Number of Nodes Vs Routing Overhead

6. Conclusion

In this paper, anovel routing protocolPSPM to predict the path stability using Markov chain has been proposedfor effective data transmission. It has been explored that the number of control packets is reduced due to selection of node with minimum Active Interactive Neighbour Rate and minimum Energy consumption. Hence, for reliable data transmission between the nodes in MANET a bi-objective optimization model is used for optimal path selection and Markov chain is used to predict the path in an effective way and the results prove that the performance of PSPM give better results compare to other protocols. In the near future, more number of parameters such as delay, bandwidth and others can be included in the determination of path selection for a multi-objective optimization problem.

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