Probabilistic Approach for Selecting Stable Path in Mobile Ad Hoc Network

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Abstract—**A mobile ad hoc network (MANET) is a self configuring network consisting of collection of mobile nodes that are connected with wireless links. The shortest path between a source node and the destination node does not always guarantee a stable path because, the topology of a MANET changes dynamically and frequently due to random motion of nodes results link failures. In this paper, we propose a probabilistic approach for selecting stable path for MANET by which instead of choosing the shortest path, we are searching for a stable route based on route expiration time, hop count, residual battery energy along with average interface traffic load. This helps not only to extend the network's lifetime but also helps to achieve load balance.**

Key Words—Link failure, MANET, Mobility of nodes, Stable path.

I. INTRODUCTION

A Mobile ad hoc network (MANET) is a self configuring network consisting of a collection of mobile nodes that are connected with wireless links [1]i.e. MANET is an infrastructure-less network [2]. These nodes serve the purpose of both hosts and/or routers and operate in an energy constrained environment. The nodes are free to move in any direction randomly and therefore mobile ad hoc networks have dynamic and rapidly changing topology. Unlike fixed wireless networks, there is no centralized control in MANET. Each node is equipped with transmitters and receivers. Nodes rely on each other to establish communication.

The characteristics of MANET make routing in MANET a challenging job as compared to the traditional computer networks. For example, while routing a packet in MANET one has to consider whether

- A path is available between the two nodes
- The path is stable
- The path is unidirectional

Power consumption is not high and so on. These are some of the many factors that one has to keep in mind while designing a routing protocol for MANET.

The MANET routing protocols are generally two types: Proactive and reactive. Proactive routing protocol [3][4][5][6] (example DSDV[7]) determine paths to all the other nodes in the network in advance and maintain those data in their routing tables. They periodically exchange routing data to maintain the paths. Hence there is minimum delay in determining the route to be taken to send the packets.

Reactive routing protocols [3][4] (e.g. DSR[8]), on the other hand, determine a route to some destination node only when it is required to send some data to that node. The source node makes a global flooding of the route request message and waits for a route reply. When it receives a route reply, it uses the route and stores it in its route cache for future use. In this case there can be a high delay before the packet is transmitted. If at any time a path fails, a path to the destination is to be determined again. There is another hybrid class of routing algorithms that takes into account the advantages of both table driven and reactive algorithms. The following diagram shows the different types of routing algorithms.

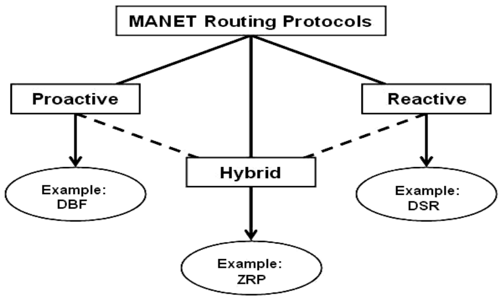

Figure 1: Routing Protocols in MANET [1]

II. RELATED WORK

In the route discovery phase of DSR, when source node S has some packets to be sent to destination node D without any known route from S to D, S broadcasts a Route Request (RREQ) packet to all the nodes of the network. If an intermediate node has already received the RREQ packet from the same source, , it then discards the packets. If N_j is the destination node, then it sends a Route Reply (RREP) message to the source by back tracing the path the RREQ arrived to it (which is recorded in route record). Otherwise, it forwards the RREQ to its neighbours (except the sender).

The source node then keeps the route information in its route cache. In [9] data is forwarded through a path whose nodes have the largest residual energy. Whenever there is any better alternative path the route is changed and switch to better route. However the path switching cost is more. In [10] the authors proposed the use of a set of sub-optimal paths occasionally to enhance the

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network's lifetime. The authors in [11] proposed an algorithm to select a more energy efficient path by relaxing a bit of residual energy. Direct diffusion [12] is good candidate for robust multipath routing and delivery. In [1], the stability of the path in DSR is based on mobility of nodes. In [13] authors proposed an energy efficient adaptive multipath routes between source to destination with low routing overhead. In [14], select the weight based reliable path considering the parameters that affect the quality of service like residue power, link stability between two nodes, error count and hop count. In [2], authors propose the load balancing scheme based on the matrices- hop count, residual battery capacity and average interface queue length.

III. PROPOSED ALGORITHM

In this paper, we propose a probabilistic approach for selecting stable path in mobile ad hoc network on demanding routing method for MANET to improve the quality of reliable routing as well as to reduce the routing overhead in MANET by using the available information of the network.

Before introducing the proposed algorithm, we define certain terms and introduce some notations to be used further.

1. Hop Count (HC): The HC is the number of hops for a feasible path. Smaller HC implies the more reliable and less cost of routing path.
2. Traffic Load (TLOAD): The TLOAD of a node is the number of packets queued up in the node's interface. Lower value of TLOAD of a node signifies the lightly loaded route.
3. Path Stability (β_k): It is the probability of a path k being stable. A path is stable if and only if all the intermediate links are stable.
4. Link Expiration Time (LET): LET represents the duration of time between two nodes. The LET can be obtained by the principle that two neighbours in motion will be able to predict future disconnection time.
5. Node Residual Energy (RES): RES is the remaining energy of each intermediate node of a path.
6. Node Required Energy (REQ): REQ is the required energy for transmitting the data packet.

We use the factor β_k to determine the stability of a route k during the Route Discovery phase of DSR. When the RREP message is forwarding from the destination node to the source node, every intermediate node send their stabilities $\beta(N_{ki})$along with the RREP message. $\beta(N_{ki})$ is calculated with the help of the information stored in the routing table maintained by each intermediate node. The source node on receiving all $\beta(N_{ki})$ and $\beta(N_{kj})$values along the path k computes the stability of the path. Alternatively, each node can cumulatively find out the stability of the path. This can be achieved by adding a PATH_STABILITY header field to the RREP message. PATH_STABILITY is initially set to 1 by the destination node. The subsequent nodes along the path update the PATH_STABILITY header by multiplying with their own stability values $\beta(N_i)$. This will reduce the computational burden of the source node.

After receiving all the RREPs, the source node then proceeds to determine the best path to the destination. For this purpose every node waits for a certain period of time waiting for multiple RREPs to arrive. Route length and stabilities can be known from these RREPs. Suppose the route k has n hops. Then length of the route is $L_k = n$.

We need not consider the stabilities of the source and destination nodes because only the intermediate n number of nodes contributes to the route stability. The stable route is then the route having maximum value of β_k .

In our approach we use RREQ and RREP packets. RREP has the following format as in Table 1.

Table 1 RREP packet format

Fields	Description
S_Id	Source Address
D_Id	Destination Address
TTL	Time –To- Live
R_S	Route to Source
PATH_STABILITY	Probability of selecting the path

In the RREP packet R_S field keeps the node's id of the path from the current node to source node.

Each node keeps the routing table with the following information as in Table 2.

Table 2 Routing Table

Fields	Description
S_Id	Source Address
D_Id	Destination Address
SeqNum	Sequence Number of the packet
HC	Number of hops traversed so far
Next Hop	Probability of selecting the path
TLOAD	Traffic load on the node
RES	Residual Energy of the node
REQ	Required Energy to transfer the data
LET	Link expiration time between the node with previous

IV. RELATED CALCULATIONS

Let $N_{k1}, N_{k2}, \ldots, N_{kn}$ are the intermediate nodes making a path k from source node S to the destination node D and $TLOAD(N_{kj})$ represents the traffic load associated with node

N_{kj} along the path k. Then presently calculated average load is defined by the following recurrence relation:

$$PCATLOAD(N_{kj}) = (PCATLOAD(N_{kj-1}) + TLOAD(N_{kj}))/2$$

With base case PCATLOAD((N_{k1}) = TLOAD(N_{k1}) ;
where $1 \le j \le n$

Since we are searching for the lightly loaded path then the probability for selecting the node N_j along the path presently consisting with j number of nodes is given by

$$P_{LOAD}(N_{kj}) = PCATLOAD(N_{kj}) / \max(TLOAD(N_{k2}), .., TLOAD(N_{kj})).$$

So, the probability of selecting the node N_j along the path k is given by $(P_{kNj})_{LOAD} = (1 - P_{LOAD}(N_{kj}))$

Hence the probability of selecting the entire path k considering only the traffic load associated with the intermediate nodes is defined as:

$$(P_k)_{LOAD} = (P_{kN1})_{LOAD} * (P_{kN2})_{LOAD} * \ldots * (P_{kNn})_{LOAD}$$

$$= \prod_{j=1}^{n} (P_{kNj})_{LOAD}$$

Let RES(N_j) represents the residual energy of the node N_j and REQ(N_{kj}) represents the required energy of node N_j along the path k for transmitting the data to the next hop along path k. Power factor of node N_j along path k is defined as :

$$PF(N_{kj}) = RES(N_j) / REQ(N_{kj})$$

In this approach we selecting only those nodes whose residual energy is greater than required energy. Since highly stable path consists of nodes having more residual energy therefore high value of PF(N_{kj}) will be acceptable. Hence 1/ PF(N_{kj}) is the probability of not selecting the node N_j along path k. Then $P_{ENERGY}(N_j)$ is the probability for selecting the node is given by $P_{ENERGY}(N_j) = (1 - 1/PF(N_{kj}))$

$$(P_k)_{ENERGY} = P_{ENERGY}(N_{k1}) * P_{ENERGY}(N_{k2}) * \ldots * P_{ENERGY}(N_{kn})$$

$$= \prod_{j=1}^{n} P_{ENERGY}(N_{kj})$$

If $(P_{kNj})_{LINK\_STABILITY}$ represents node's N_j probability of stability along the path k due to LET then $(P_{kNj})_{LINK\_STABILITY}$ is defined by

$$(P_{kNj})_{LINK\_STABILITY} = 1 - LET(N_{kj-1}, N_{kj}) / \sum_{j=0}^{n} LET(N_{kj}, N_{kj+1})$$

Where LET(N_{k0}, N_{k1}) represents the link expiration time between the source node S and the first intermediate node along the path k. LET(N_{kn}, N_{kn+1}) represents the link expiration time between the last intermediate node and the destination node D along the path k.

Therefore the probability of selecting the k path with n number of intermediate nodes between source node S and the destination node D is given by the following equation:

$$(P_k)_{LINK\_STABILITY} = (P_{kN1})_{LINK\_STABILITY} * (P_{kN2})_{LINK\_STABILITY} * \ldots * (P_{kNn})_{LINK\_STABILITY}$$

Or, $$(P_k)_{LINK\_STABILITY} = \prod_{j=1}^{n} (P_{kNj})_{LINK\_STABILITY}$$

Considering link expiration time, traffic load and residual energy associated with the each intermediate node along the path k consisting of n number of intermediate nodes is defined by:

$$\beta_k = (P_k)_{LINK\_STABILITY} * (P_k)_{LOAD} * (P_k)_{ENERGY}$$

V. CASE STUDY

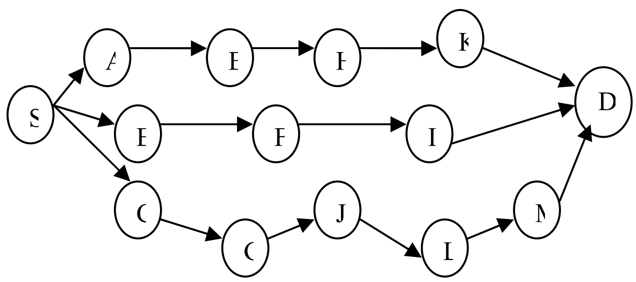

Figure 2: Multiple path from S to D

Consider the network where S is the source node and D is the destination node and the following information associated with each intermediate node.

TLOAD(A) =45, TLOAD(B) =51, TLOAD(C) =17,
TLOAD(E) =37, TLOAD(F) = 50,TLOAD(G) =37,
TLOAD(H) =35, TLOAD(I) = 45,TLOAD(J) =30,
TLOAD(K) =29, TLOAD(L) = 39,TLOAD(M) =39.

RES(A) =250, RES(B) =130, RES(C) =420, RES(E) =300,
RES(F) = 430,RES(G) =330, RES(H) =350, RES(I) =340,
RES(J) =230, RES(K) = 290,RES(L) =240, RES(M) = 220.

LET(S,A)=32, LET(A,E)=60, LET(E,H)=20, LET(H,K)=18,
LET(K,D)=44,LET(S,B)=20, LET(B,F)=30, LET(F,I)=15,
LET(I,D)=10, LET(S,C)=30,LET(C,G)=36, LET(G,J)=42,
LET(J,L)=30, LET(L,M)=44, LET(M,D)=20.

Here LET(P,Q) represents the link expiration time between node P and node Q.

In [2], Average traffic queue on $PATH_I$[SAEHKD] is 36.5.
Average traffic queue on $PATH_{II}$[SBFID] is 48.6.
Average traffic queue on $PATH_{III}$[SCGJLMD] is 32.4.
Route Energy of $PATH_I$ is min (250,300,350,290) = 250.
Route Energy of $PATH_{II}$ is min (130,430,340) = 130
Route Energy of $PATH_{III}$ is min(420,330,230,240,220) = 220.
Since average traffic queue on $PATH_{III}$[SCGJLMD] is smallest among all existing paths, therefore from the view of

traffic queue $PATH_{III}$ is preferable.

Since Route Energy (minimum of residual energy of nodes falling on a path) of $PATH_I$ is maximum then $PATH_I$ has the lesser probability of route failure.

In [14] for $PATH_I$, RET = min(32,60,20,18,44) = 18

For $PATH_{II}$, RET = min(20,30,15,10) = 10

For $PATH_{III}$, RET = min(30,36,42,30,44,20) = 20.

Since $PATH_{III}$, has largest RET obviously $PATH_{III}$, is more stable among others existing routes between source to destination.

In our method, let REQ(Nj) = 100; where Nj is any intermediate node between S to D.

PCATLOAD(A) =45

PCATLOAD(E) =(45+37)/2 =41

PCATLOAD(H) =(41+35)/2 = 38

PCATLOAD(K) =(38+29)/2 = 33.5

$P_{LOAD}(E) = 41/\max(41,45) = 0.911$

$P_{LOAD}(H) = 0.844$

$P_{LOAD}(K) = 0.744$

$(P_1)_{LOAD} = (1-0.911)*(1-0.844)*(1-0.744) = 3.55 \times 10^{-3}$

$(P_1)_{ENERGY} = 0.6 * 0.66 * 0.715 * 0.655 = 185.45 \times 10^{-3}$

$(P_1)_{LINK\_STABILITY} = 0.817 * 0.656 * 0.886 * 0.897 * 0.747$

$= 318.17 \times 10^{-3}$

So, for $PATH_I$, $\beta_1 = 209.46 \times 10^{-6}$

Similarly for $PATH_{II}$, $\beta_{II} = 0.640 \times 10^{-3} * 124.36 \times 10^{-3} * 0.305$

$= 24.27 \times 10^{-6}$

For $PATH_{III}$, $\beta_{III} = 557.6 \times 10^{-6} * 27.09 \times 10^{-3} * 331 \times 10^{-3}$

$= 5.00 \times 10^{-6}$

Therefore, as per our method $PATH_I$ is the most stable path considering the parameters route expiration time, residual battery energy along with average interface traffic load.

VI. CONCLUSION

In this paper, we propose a routing algorithm with greater stability by maximizing the probability of stability among the feasible paths. Worked examples shows that the proposed algorithm gives the better routes with the existing algorithms.

In future work the implementation of the proposed algorithm will be done using Network Simulator-2 and various simulation results will be studied and compared with the existing algorithms.

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