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Stable Multipath Routing Protocol using Different Route Selection Mechanism for Mobile Ad-hoc Networks

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Abstract

Mobile ad- hoc networks (MANETs) are self-organizing network communication happens through single hope or multi-hope without the support of any infrastructure. Designing a routing protocol is a crucial issue in MANET because of infrastructure less and highly dynamic topology. The determined routing path between any pair of nodes is of type single path or multipath, among this multipath is preferred because alternate path is used when the primary path fails. The author proposes a multi-path routing algorithm, which select multiple paths with minimum control overheads (OH). In this approach multipath selection is carried out using three different schemes called short-multipath, stable-multipath, and short-stable multipath. Link stability among several nodes in the selected path is calculated among those values minimum value denotes path stability because a path is no stronger than its weakest link. Simulation was done in network simulator 2, shows that the proposed system performs well when compare with any other protocols, even in highly dense network.

Key Words:SMR, DSR, OLSR, OH.

1. Introduction

MANET **(**Mobile ad hoc network) Abolhasan, M *et al* (2004) is a collection of wireless nodes capable of establishing a dynamic route for exchanging data among themselves, without any infrastructure or centralized administrator. MANET's are characterized by dynamic topology, highly vulnerable to security threats, limited energy level, and bandwidth. Due to these features designing a routing protocol is a major issue in MANET. A myriad number of routing algorithms are proposed in the literature which deals this dynamic nature through reactive or proactive or a combination of both.

Proactive protocols uses table to maintain up-to-date information about topology. A stable path was formed by using these routing tables Clausen T *et al* (2004). Reactive protocols/on- demand Perkins, C.E et al (1999); Johnson, D et al (2007); Hass, Z.J., (1997); Joa-Ng, M. and I.T. Lu, (1999) will establish routes when there is a packet to be transmitted between any pair of nodes. Thus, saving energy level, bandwidth and reducing overhead is achieved. Routing protocol forms a single route between any pair of nodes. If there is link failure due to node mobility requires re-determination of routing path.

Multipath routing protocol Tarique, M et al (2009) establishes multiple paths between any pair of nodes. Data was transmitted through a selected path and the rest of path was used as backup paths. When there was a link failure due to node mobility network can able to survey with the help of backup path.

MANET's routing protocol design is NP-hard because of node mobility. Node mobility lead to frequent change in topology, due to this maintaining up-to-date information is difficult. The proposed algorithm focuses on these issues by analyzing link stability through life time prediction.

2. Related Works

OLSR was a table driven routing protocol uses effective flooding to reduce routing overheads which were achieved through Multipoint Relays (MPRs). A node can act as MPR if it covers several nodes in the next level. This approach will avoid bandwidth efficient paths, even though such path exists.

In OLSR versions Badis, H et al (2003) while selecting multi-point relays they consider the node which covers several nodes in next level as well as bandwidth. This approach selects a bandwidth efficient path, but it does not reduce loops during route establishment.

Bandwidth Efficient Multi-point Relays in Optimized Link State Routing BEMPRs-OLSR Alagiri et al (2012) it uses a similar algorithm like OLSR version. In this method a queue is used to maintain all the nodes that are competing to act as multi-point relays. The node acting as MPRs generates a loop, then it should be removed from the queue and the next node in the queue was allowed to act as MPRs.

Sujata et al (2016) A node was selected as candidate nodes if and only if it is having high enduring bandwidth, enduring power, link quality and less mobility. Through these candidate nodes multiple paths are established between source and destination. Alternate path through other candidate node is established, If any candidate node in the path tend to fail due to lack of bandwidth, energy or link quality.

Fabian Rump et al (2016) Many MANET routing protocols under perform during dense scenarios with high network load. In these situations, a high level of route instability, which is often called "route flapping". To Increase route stability in dense scenarios with high network load the proposed PRIME routing protocol uses a probabilistic multipath forwarding process.

Many existing multipath routing protocols proposed in littérateur are, modified versions of single path routing protocols: DSR and SMR Lee, S.J. and M. Gerla, (2001) AODV and AOMDV Marina, M.K. and S.R. Das (2001) all these protocols are on-demand routing protocols. Most of the researchers are concentrating on-demand routing protocols because of high network performance.

On demand routing protocols generate several route requests to an intermediate node for establishing path. Duplicate route request was discarded by an intermediate node which increases redundancy Yao, Z et al (2003)

Kuhn et al (2005) proposes another version of OLSR using IP-source routing, node disjoint multi-path route computation was done using the Dijkstra algorithm. The determined routing path was inserted in the packet IP - header before sending. Load balancing was achieved by finding path congestion information. Congestion information was measured as maximum size of the queue in intermediate nodes of that particular route. This information’s are encapsulated in HELLO packets and advertised in Topology Control (TC) message.

Nodes in the network were classified as used and unused node Zhou, X et al (2005). Unused nodes are alone considered while establishing multiple paths. This will increase additional control overheads in the network.

Shortest-widest path algorithm Badis, H et al (2004) was used to calculate multiple paths. The QOLSR routing protocol was an extended version of the OLSR routing protocol in that bandwidth and delay metrics are used, but in practical maintaining bandwidth and delay was sparingly difficult.

A multipath Dijkstra algorithm called Multipath Optimized Link State Routing (MP-OLSR) Yi, J et al (2010) to calculate multiple paths between any pair of nodes. MP-OLSR was a hybrid protocol mainly concentrates about loop detection and route recovery in source routing.

Energy consumption and remaining battery power as a metric to Vazifehdan, J et al (2012) increase the life of node-to node communication. Analysis was done by considering a network that supports Automatic Repeat Request (ARQ) and the network don't support ARQ.

Split multi-path routing (SMR) Marina, M.K. and S.R. Das, (2001) uses maximally disjoint paths while establishing route from source to destination. A pure source routing strategy seems are not suitable for highly dense network and route error messages increase delay when compare to route recovery.

LSLP protocol Mamun-Or-Rashid, M. and C.S. Hong, (2007) in which Qos metric was used along with lifetime prediction. The LSLP protocol was a single path protocol. Lime time of primary path alone was determined to reduce packet retransmission.

From literature author identified that QoS service metric like bandwidth, hop count, remaining battery power, the size of the congestion window is considered during route discovery. Node mobility causes frequent link breakages, so it is to be considered during route discovery. In this study, the author proposes a new Multipath Lifetime Prediction (MPLP) algorithm to reduce data retransmission by analyzing mobility.

3. System Model

Next Hop Availability (NHA)

NHA is used while determining a routing path between any pair of nodes. Link and node availability metrics are used to compute NHA. NHA is calculated as follows

$$NHA = Link_{prob} + Node_{prob}$$

Huge numbers of packets are traveled through the same set of nodes energy level of the nodes gets depleted soon, due to this link break happens frequently. Remaining battery power is having a direct impact over route lifetime, so the energy level is used as a metric in finding node probability. Node probability is demonstrated in terms of the remaining battery power B_r and maximum battery power B_m. Node probability is expressed as follows

$$node_{prob} = \begin{cases} 1 & if\ B_r \geq 20\% \\ \dfrac{B_r - 5}{Bm} & if\ B_r < 20\%\ and\ B_{r \geq 5\%} \\ 0 & if\ B_r < 5\% \end{cases}$$

Link probability LP_{ij} is expressed as

$LP_{ij} = freeslots\,of\ (n_i) \cap freeslots\,of\ (n_j)$

MANET Model

MANET is represented as a connected graph $G = (V, E)$ as shown in fig1, were E denote the set of bidirectional edges and V denotes the set of nodes in the network. The metrics associated for $\forall e \in E$ being bandwidth, delay and hop count.

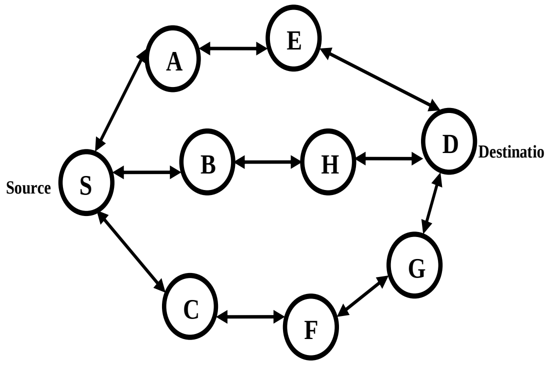

Figure 1: Mobile Ad-Hoc Network

For any arbitrary route R delay is expressed as

$$D(R) = \sum_{e \in R} D(e) + \sum_{n \in R} D(n)$$

Bandwidth is expressed as

$$B(R) = \min(B(v_i, v_{i+1}), B(v_{i+1}, v2) \cdots, B(v_{k-1}, v_k))$$

Were v_i and v_j are source and destination nodes.

Any given metric can be classified as concave, additive and multiplicative metric. Concave metric is expressed as minimum costs of the individual links in that route. The sum of the costs of all individual links in a router is called an additive metric. Multiplicative metric is defined as the product of the costs of individual links in a path. Hence, bandwidth and link lifetime are concave metric were as end-to-end delay is an additive metric

The hop count is denoted as the number of nodes that are visited in that particular path.

$Hop\ count(p(i)) = count(v_i)\ ; v_i \in p(i)$ Hop count and delay metrics are not used while selecting a primary path from multiple- path, since the time taken for a route request (RREQ) to reach a destination is high if these metrics are high.

Let's consider two nodes i and j are in the transmission range of each other and the coordinates are (x_i, y_i) and (x_j, y_j) respectively. Let (v_i, v_j) are the speeds of mobile node i and j there moving direction are (θ_i, θ_j), $(0 \le \theta_i, \theta_j < 2\phi)$ respectively. Link Expiration Time (LET) of connected nodes i and j are calculated as follows,

$$LET = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2}$$

Were

$$a = v_i \cos\theta_i - v_j \cos\theta_j$$
$$b = x_i - x_j$$
$$c = v_i \sin\theta_i - v_j \sin\theta_j$$
$$d = y_i - y_j$$

The path stability value is calculated as follows

$$P(R) = \min(LET(v_i, v_{i+1}), LET(v_{i+1}, v2)\cdots, LET(v_{k-1}, v_k))$$

Were v_i and v_j are source and destination nodes.

4. SMPR-Stable Multipath Routing for MANET

SMPR is an on-demand multipath routing algorithm for MANET, it determines route to destination, whenever there is a need for data transmission. The proposed approach consists of four different phases, namely, topology sensing, route discovery, route replay and route error. The proposed algorithm is implemented by using four control messages, namely, hello, route request (RREQ), route replay (RREP) and route error (RERR).

Topology Sensing

Topology sensing is done with the help of a control packet called a hello packet. Hello packet format is shown in Fig2 consist of packet type and starting time. A hello packet is transmitted a node will be received only by its 1-hop neighbor. Neighbor nodes advertise the receiving time of hello packet to its sender. Sender node will calculate available bandwidth of each outgoing edge based on starting, received time and size of hello packet. An entry will be made in the neighbor table for the node that reports receiving time of hello packet along with its bandwidth. The neighbor table gets updated for each subsequent hello packet to maintain the status of outgoing edge.

Packet-Type=hello	Starting time

Figure 2: Hello Packet Format

Route Discovery

Source wants to send a data to an arbitrarily selected destination, it enters into route, discover phase by generating RREQ packet. Route request packet is shown in Fig3. The generated RREQ packet is broadcasted to its neighbor node. RREQ packet will collect local information about the nodes. The neighbor node is allowed to forward the RREQ packet to the next level only when it satisfies $NHA>NHA_{thr}$ so routing overhead (OH) is controlled.

When an intermediate node receives a RREQ message first it checks whether its own IP_address is already present in IP_stack, if so, it will discard the RREQ packet, otherwise it will append its own IP_address in IP_stack and forward it to the next level. RREQ pseudo is shown in Fig4.

Field Name	Filed specification
Packet_Type	RREQ
RREQPSN	RREQ packet Sequence Number used to identify unique RREQ
TTL	Packet Time-To-Live
Coordinates	Coordinates of current node to compute LET
Bandwidth	Link bandwidth
LET	Link Expiration Time
Hop count	Hop count
S IP_Address	Source IP_address
DIP_Address	Destination IP_address
IP_Stack ⋮	Node list

Figure 3: Field Specification of RREQ

```
/*---------Forward path---------*/
if node==Source S
     Generate RREQ
     Broadcast to neighbors
while node== intermediate node (IMN)
     if  (NHA<NHA_thr)
     if!(IP_IMN is present in RREQ IP_stack )
    then
          discard REQ
    else
          update IP_address in RREQ IP_satck
```

Figure 4: RREQ Pseudo-Code

Once RREQ packet reaches the destination node, it will adopt three different schemes to generate RREQ. These three different schemes are called shot_multipath (SMP), stable_mutipath (STMP), and short-stable_multipath

(SSTMP). Field specification of RREP packet was shown in Fig5.

Field Name	Filed specification
Packet_Type	RREP
SoureIP_Address	Source IP_address
DIP_Address	Destination IP_address
TTL	Starting time
IP_Stack ⋮	Node list

Figure 5: Field Specification of RREP

The main objective of the short - multipath scheme is to minimize end-to-end delay in the network by selecting two shorter routes. In this scheme destination node sends RREP to source node once it received the first RREQ and this route is considered as first route. To select the second shortest route the destination uses the information available in first RREQ and wait for time T_W to collect other RREQ packets. A feasible path exists from source to destination in each and every RREQ that are collected during T_W the time. The destination node selects node disjoint route from the mule-path collection in terms of information provided by first feasible route. If such route does not exist, it will select link disjoint routes. In both the cases more than one route exists LET is used to break the tie. This approach will avoid bandwidth efficient paths, even though it exists and the energy depletion is more in the shortest path due to excessive traffic.

```
Route= NodeDisjointRoute();
If (No of routes ==0)
{
    Route= LinkDisjointRoute();
    If (No of routes >1)
        Route=SelectRoutewithMaxLET();
    Else If (No of routes>1)
        Route=Select RoutewithmaxLET();
}
```

Figure 6: Short-Multipath Pseudo Code

Stable-multipath scheme is proposed to use bandwidth effectively. In this method, destination node doesn't generate RREP for this first RREQ, it receives, it will wait for T_W time to receive multiple RREQ and finally it gets a multipath collection. Destination selects a select a route with maximum LET as a first route to generate RREP if more than one route exist, then the route with maximum LET will be selected. The destination node selects node disjoint route from the multi-path collection in terms of information provided by first feasible route. If such route does not exist, it will select link disjoint routes. In both the cases more than one route exists hop count is used to break the tie. This approach will select a stable route, but network delay is more.

```
Route=SelectRouteWithMaxLET();
If (Route t>1)
            SelectRouteWithMinhop();
            Route= NodeDisjointRoute();
If (Route = =0)
{
            Route=LinkDisjointRoute();
            If (Route >1)
            {
             Route =SelectRouteWithMaxLET();
             If (Route >1)
                Route=SelectRoutewithMinHop();
            }
}
 Else If (NodeDisjointRoute >1)
{
            Route=SelectRouteWithMaxLET()
            If (Route >1)
                        SelectRoutewithMinHop();
}
```

Figure 7: Stable-Multipath Pseudo Code

Short-stable-multipath scheme is proposed by combining the advantage of the earlier method. In this method, destination node generates RREP packet to source immediately when it receives the first RREQ. The destination node waits for time T_w to collect remaining RREQ.

The destination node selects node disjoint route with maximum LET from the multi-path collection in terms of information provided by first feasible route. If such route does not exist, it will select link disjoint routes. In both the cases more than one route exists hop count is used to break the tie.

```
Route = NodeDisjointRoute();
If (Route = =0)
{
            Route=MaxLinkDisjointRoute();
            If (Route>1)
            {
                        Route=SelectRouteWithLET();
                        If(Route count>1)
                       SelectRoutewithMinHop();
            }
}
Else If (NodeDisjointRoute >1)
{
            Route=SelectRouteWithMaxLET();
            If(Route>1)
                        SelectRoutewithMinHop();
}
```

Figure 8: Short-Stable-Multipath Pseudo Code

Route Maintenance

The state of routes determined by the route discovery phase is monitored by route maintenance phase. This phase is responsible to identify route invalidity and prevents source node form transferring data through that invalid path. Once SMP recognizes there is a link failure, it generates RERR to the source node. The nodes that are in between interrupted node and source node drop all the packets that are yet to send in queue. The source node removes all entries from its route table related to broken link after receiving RERR control packets. In all three proposed schemes SMPP uses two different routes, if any one route session fails source uses the other route to send data. The source node generates a new route request only when both route sessions are invalid. Field specification of the RERR is shown in Fig9.

Field Name	Filed specification
Packet_Type	RERR
IP_stack	Non reachable nodes IP

Figure 9: Field Specification of RERR

5. Results and Discussion

SMP performance is analyzed based on the assumptions widely used in literature (Zhang Q, Agrawal DP 2005)

1. All mobile nodes in the network are homogeneous nodes.
2. Nodes should capable of identifying corrupted packet and discard it.
3. Every node in the network should participate fully in each and every event occurs in the network. Particularly, it should not hesitate to forward the packets to other nodes.

The proposed SMP algorithm compared with protocols like DSR, SMR. Simulations are carried out in NS2 with the parameters shown in Table 1.

Table 1: Simulation Parameters

Parameter	Values
Transmission Range	250m
MAC layer protocol	IEEE802.11
Traffic Pattern	CBR
Data Packet Size	1024 bytes
Simulation area	1000mX 1000m
Number of Nodes	100
Mobility	0-10 m/s
Mobility Model	Random way point model

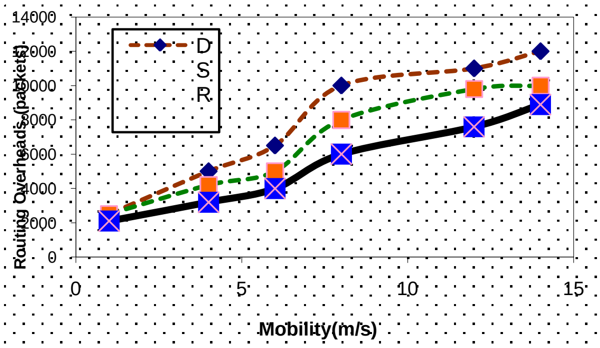

Figure 10: Routing Control Overheads

Routing control overhead performance comparison is shown in Fig10. From the figure it’s clear that routing overhead is directly proportional to mobility. Link connectivity between the nodes changes frequently when mobility increases, which lead to often link break. New routes will be determined to carry out data transmission, so routing control overhead of DSR, SMR and SMPR go up. Almost all protocols in comparison are having same routing overheads when mobility is less. SMPR has less routing overhead when compare to DSR and SMR when mobility is high, since SMPR reconstruct the route when both the route session fails were as the others reconstruct the route when the primary root fails. The LET is used as a metric in finding multiple paths, so the source will transfer the data only with that time limit so it avoids rebroadcast of the data packet.

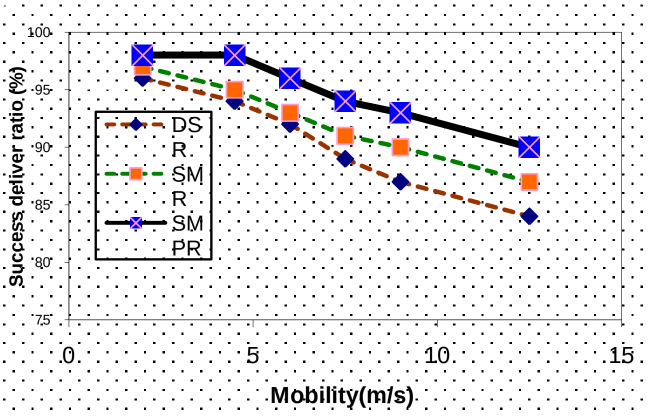

Figure 11: Packet Delivery Ratio

The network throughput is directly proportional to loss rate. The packet delivery ratio is an important metric since it is used to measure loss rate. Mobility increases packet delivery ratio decreases because of frequent link break. Fig 11 shows the packet delivery ratio of three different protocols. SMPR is having a high packet delivery ratio when compare to the SMR and DSR. The reason is node stability, link stability is considered in SMPR, when an invalid link is notified by an intermediate node the source node selects the other path for data transfer without any interrupt. Numbers of nodes in the network are high packet delivery ratio increases, due to high availability of links.

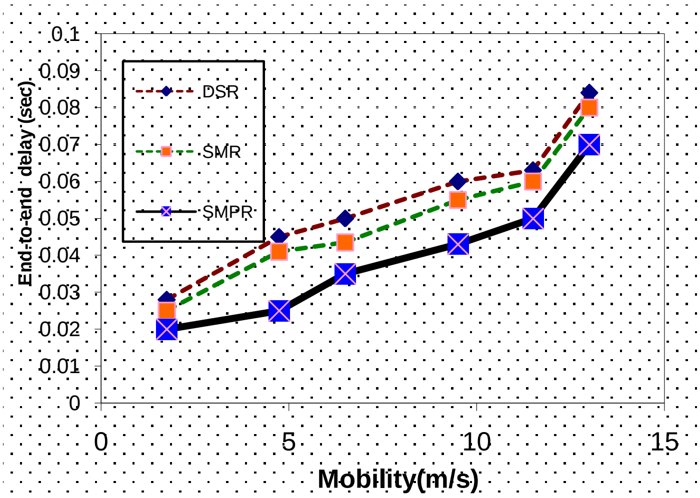

Figure 12: End to End Delay

End-to end delay of a path is defined as the sum of delay happens in nodes and links in that particular path. End-to-end delay is illustrated in Fig12. Delay of a route increases if route reconstruction happens frequently, the reason is data packets as to wait in queue until a valid route is formed. SMPR is having a shorter delay when compare to the other protocols since the lesser number of route reconstructions happen. When one route is invalid SMPR uses the remaining available route, so it doesn't require any additional latency.

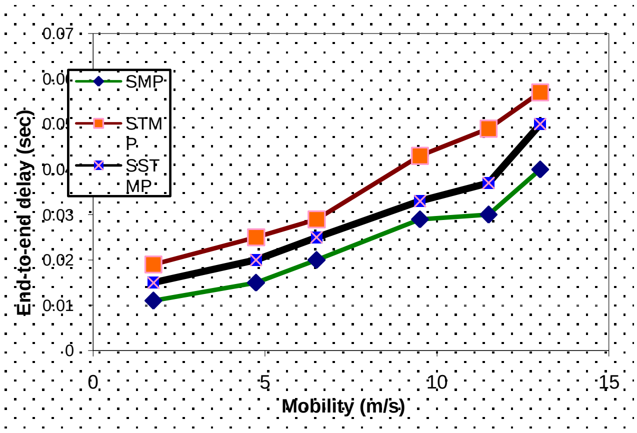

Figure 13: End to End Delay

Fig13 shows the comparison of end-to-end delay of all three proposed schemes. SMP is having a minimum delay when compare to the other two because RREP is generated for first route REQ itself an obvious corresponding path is the shortest path. STMP scheme generates stable path, but there is no surety that the corresponding path is the shortest path, so the delay of that scheme is high when compared to SSTMP. SSTMP scheme delay more when compared to SMP, and less when it is compared to STMP since the shortest stable path is selected for routing.

6. Conclusion

Multipath routing protocols can improve the performance of Ad-hoc networks because of its nature of finding multiple paths. In this paper the proposed algorithm, SMPR uses link prediction model to predict the line break, so that a stable path can be selected among the multiple paths. Through simulations it was demonstrated that SMPR perform well when compared to any other protocols.

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