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Research Article

Analysis of Multipath Routing in Random Ad Hoc Networks Scenario

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Abstract: In this study, we have proposed a multipath routing protocol for Mobile Ad Hoc Networks. Multipath routing overcomes various problems that occur in data delivery through a single path. The proposed protocol selects multiple neighbor nodes of source node to establish multiple paths towards destination. These nodes are selected based on their minimum remaining distance from destination. We have computed the length of various paths and average hops count for different node density in the network. We have considered only three paths for our evaluation. The results show that path-2 gives better results in term of hop count and path length among three paths.

Keywords: Average number of hops, distance, hop count, neighbor nodes, path length, probability

INTRODUCTION

A Mobile Ad-hoc Network (MANET) (Siva and Manoj, 2008; Ram and Redi, 2002) is an inter-connection of autonomous mobile hosts (mobile devices i.e., mobile phone, laptop, iPod, PDAs etc.) that can communicate without any support of infrastructure. A source (S) node can send data to a Destination (D) directly, if the source and destination are within the transmission range of each other. Otherwise intermediate nodes help to relay data from source to destination. In MANET individual node can leave and join the network on its own. Therefore, the physical connection in the network can dynamically change. Battery power of mobile device is also important in the network because depletion of battery power may result in partition of the network. The mobility nodes, also impacts the topology of the network. Due to dynamic topology (Marjan *et al*., 2012) of the network routing in MANET is a challenging issue. Single path routing is not always sufficient to disseminate data toward destination. Therefore, multipath routing becomes important and serves well.

In this study we have proposed a multipath protocol assuming that there are k (k = 1, 2, 3…) paths between source and destination pair. Next hop nodes are selected based on their minimum remaining distance from destination node. For the analysis of the protocol we have computed average path lengths of various paths and hop count. Through this we want to find best possible three paths among k paths based on minimum hop count and minimum path length.

LITERATURE REVIEW

Multipath routing overcomes various problems that occur in data delivery through a single path. Data delivery technique suing single path may encounter failure in message delivery and require further retransmission of the messages. Initiation in route discovery for retransmission consumes network resources i.e., battery power and bandwidth. Therefore, multipath is one of the best possible solutions to overcome this problem where delivery of data is a prime matter of concern. Researchers and Academicians has proposed and implemented many multipath routing protocols. However, these protocols have been designed with specific objectives to achieve. The main aim of multipath routing protocols is to reduces the use of scarce network resources i.e. battery power, bandwidth. Further, multipath routing may cope with fault occurrence, reduces overall message delivery delay, distribute load or traffic to various paths and ensure the guarantee of message delivery. Multipath routing protocols are broadly classified as on-demand, table driven and hybrid protocols.

M-DSR (Multipath Dynamic Source Routing) (Tsai and Moors, 2006; Nasipuri and Das, 1999) is an on demand routing protocol that is a multipath extension of DSR (Johnson *et al*., 2003). Generally, on demand protocols use flooding for message delivery which consumes a large portion of network bandwidth. The route discovery process is follows query flooding which reduces the bandwidth consumption. The advantage of multipath routing is that it reduces the

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frequency of query flooding. There are two varied version of M-DSR:

- Only source gets the multiple alternate routes
- Each intermediate node on the primary route gets an alternate route

The analytical analysis of results shows that any form of multipath technique always performs better than single path in terms of route discovery. Further, large alternate path are not efficient as they tend to break easily. Alternate routes with some bound are of only use. The highest performance is achieved up to maximum of two paths.

SMR (Split Multipath Routing) (Tsai and Moors, 2006; Lee and Gerla, 2001; Aristotelis and Haas, 2001) is an on demand routing protocol and is also an extension of well- known DSR protocol. The main aim of this protocol is to split the traffic into multiple paths so that bandwidth utilization is done in an efficient manner. Ad hoc on demand Multipath Distance Vector (AOMDV) (Jiazi *et al*., 2011; Tsai and Moors, 2006; Stephen *et al*., 2004; Perkins *et al*., 2003; Mahesh and Das, 2001, 2006) protocol is a multipath variation of AODV protocol. The main objective of this protocol is to achieve efficient fault tolerance i.e., quick recovery from route failure. The protocol computes multiple links disjoint loop free paths per route discovery. If one path fails the protocol switches to other available paths. The route discovery process is initiated only when a particular destination fails.

TORA (Temporary Ordered Routing Algorithm) is a highly adaptive, efficient and scalable distributed routing algorithm developed based on link reversal algorithm (Park and Corson, 1997). The protocol works efficiently for large and dense network. TORA is source initiated and reactive multipath routing protocol. This algorithm creates a Directed Acyclic Graph (DAG) which is destination oriented. In TORA control messages are localized to a very small set of nodes near the occurrence of a topological change. To know the changes the nodes maintain routing information about adjacent nodes. The protocol works in three phases:

- Creating routes
- Maintaining routes
- Erasing routes

It uses three distinct control packets, Query (QRY), Update (UPD) and Clears (CLR). The QRY packets are used for route creation, UPD packet for creating and maintaining the route and CLR packet for erasing invalid routes. Route creation is initiated when a node with no directed links requires a route to the destination. Therefore, route creation is actually assigning directions to links in an undirected network or portion of the network. In GMR (Graph based Multipath Routing) (Tsai and Moors, 2006; Koh *et al*., 2003) protocol destination node computes disjoint path in a network using network topology graph. This protocol uses source routing as it follows DSR. But the difference with DSR is that in this protocol each RREQ packet has graph information which includes abstract network topology (RPG). Intermediate nodes that receive RREQ packet for first time further wait for a predetermined time for more RREQ packets. If an intermediate node receives more than one RREQ packet, it merges graph information with the previous graph. After time out it rebroadcast the RREQ packets. The destination node after getting the first RREQ packet it also waits for more RREQ packets. After timeout the destination node computes link disjoint paths and reply to the source through multiple paths using multiple RREP packets.

MP-DSR (Tsai and Moors, 2006; Esmaeili *et al*., 2006; Leung *et al*., 2001) is also an extension of DSR; is design to improve QoS support with respect to end-to end delay. For route discovery this protocol calculates end-to-end reliability requirement value p_u.Ifp_u is given, MP-DSR determines the following two parameters:

- The number of paths it needs to discover (m_o)
- The lowest path reliability requirement (π_{lower}) that each search path must be able to satisfy in order to meet end-to-end reliability requirement

End-to-End path reliability p (t) of a path, is calculated as the product of link availability of all the links in the path. In other words, P (t) is the probability that at least one path stays connected for the duration of t. The route discovery process is initiated by a source that sends RREQ to m_o neighbors after determining the path reliability requirement is greater than the lowest path reliability requirement. After receiving RREQ an intermediate node checks path reliability requirement. If the requirement is satisfied, it sends RREQ to the maximum m_o neighbors, otherwise discards the RREQ. For path selection the destination waits for a pre-determined time which is set after receiving the first RREQ packet. Then the destination node executes path selection algorithm and sends RREP packet to the source one for each RREP message. A path selection algorithm have two major steps:

- The first is path sorting algorithm which store all feasible paths
- The second is disjoint path selection that select a group of disjoint paths

All disjoint paths may collectively satisfy p_u. For route maintenance two scenarios may occur:

- When the time window t_w at the source node expires, it updates the reliability before deciding whether a new route discovery is necessary
- When all paths are broken source node immediately initiates a new route discovery without any examination

Toussaint (2003) and Sung and Gerla (2000) have proposed an on-demand multipath routing protocol

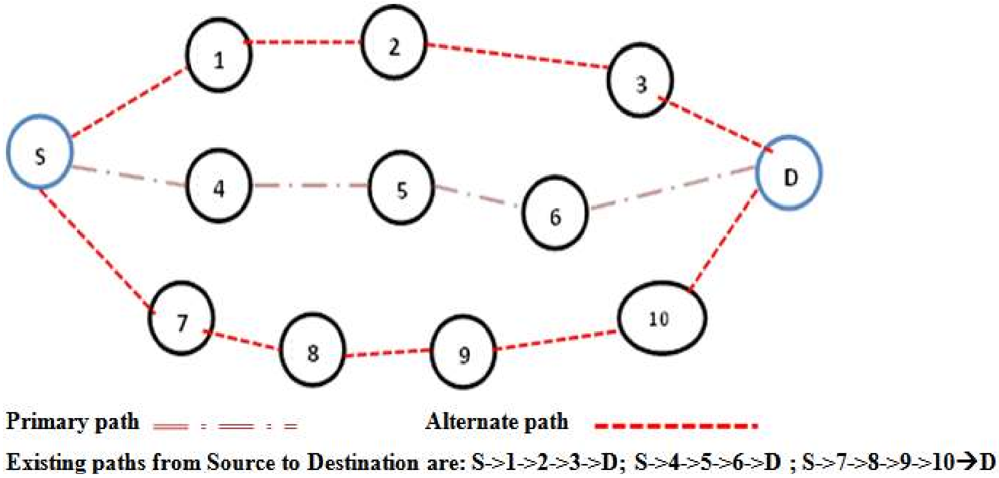

Fig. 1: A simple scenario of multipath routing

AODV-BR that establishes multipath without spending extra control message. This protocol utilizes mesh structure to provide multiple alternate paths. This scheme is inspired by the dual routing protocols. When a primary path fails to deliver messages, multiple alternate paths are utilized. The route construction phase follows the same procedure as followed by AODV. When a source node does not have any route information and needs a route to the destination, it floods Route Request (RREQ) packets in the network. An intermediate node after receiving RREQ packets checks the unique identifier and drops the packet, if it is a duplicate RREQ packet. Upon receiving an original RREQ packet, if an intermediate node has route to the destination or it is the destination node, it sends Route Reply (RREP) packet to the source. The destination node sends a RREP packet through the selected route. A selected route is the route recorded when the first RREQ arrives or subsequent RREQ packets that traversed a better route. The alternate routes are established during the route RREP phase. A node promiscuously overhears packets which are transmitted by their neighbor nodes. Through this overhearing a node collects alternate path information. Multiple routes forming a fish bone structure (Toussaint, 2003) record a neighbor in its alternate route table by overhearing the route reply packet. In this way a node may receive many Route Reply (RREP) packets for the same route but select the best one to be inserted in its alternate route table. The primary route and alternate routes together establish mesh structure which is similar to fish bone like. Route maintenance phase is initiated when a route fails. It performs one hop data broadcast to its intermediate neighbors. A node specifies in the data header that the link is disconnected and the packet is a candidate for alternate route. The neighbor nodes which have an alternate route to the destination unicast packets to their next hop nodes. Like this data packets are delivered through one or more alternate routes and therefore are saved from being dropped.

Table 1: Symbols and notations

Symbols	Description
S	Source node
N	Total number of nodes
R	Radio transmission range
D	Destination node
D_{sr}	Distance between source and destination
N_i	Total number of neighbor nodes of node i
L_k	Path length of path k, where, k = 1, 2, …n
H_k	Hop counts for path k, where, k = 1, 2, …n
A	Area covered by a node
d_{11}	Distance between source and 1st node of path 1
d_{21}	Distance between source and 1st node of path 2
d_{31}	Distance between source and 1st node of path 3

METHODOLOGY

System model: A simple scenario of multipath routing is shown in Fig. 1.

The probability of n nodes present within a network area A with average node density λ is calculated as (Table 1):

$$P\{n\} = \frac{(\lambda A)^n \times e^{-\lambda A}}{n!} \tag{1}$$

According to proposed model data from source node to destination node is delivered through multiple paths. Therefore, source node must have more than one neighbor nodes to establish multiple paths. The probability of source node having N_i neighbor node is computed as:

$$P\{N_{\text{neighbour}}\} = \frac{(\lambda \Pi R^2)^n \times e^{-\lambda \pi R^2}}{n!} \tag{2}$$

The proposed protocol based on multi-hop forwarding method. In ad hoc networks it's seldom that source and destination node fall in each other transmission range. Therefore, data from Source (S) is transmitted to Destination (D) with the help of intermediate nodes. Here, we have considered multiple paths from source to destination. It is needed because data through single path may not always be delivered to the destination. Therefore, data delivery through multiple paths or alternate path is always guaranteed in a connected network. We have proposed a Multi-Next Hop Selection algorithm (MNHS) to identify nodes for establishing multiple paths from a source node. The next hops are selected based on their minimum remaining distances from *D*.

Multi-next hop selection algorithm: We assume that a source node *S* has N_i number of neighbor nodes. Source node *S* computes the distance of all neighbor nodes from itself:

$S = \{n_1, n_2, \ldots, n_i\}$, where $i = 1, 2, 3, \ldots, N$
and $N \neq 0$

Compute distance D_i of i^{th} neighbor node from the source node where, $i = 1, 2, 3, \ldots, N$.

To establish multiple paths source node *S* selects more than one node from the neighbors to establish multiple paths. A source node selects neighbor nodes having maximum distance from source node or maximum progress towards destination In Fig. 1, we have considered three paths. Therefore, three nodes are selected from neighbor nodes of the source node *S* and three paths are established. Nodes are selected using Eq. (3) to (5) given below.

Step 1:

$$S \{\text{select node } n_1\} = \text{MAX } \{D_1, D_2, \ldots, D_i\} // n_1 \text{ selected for path 1} \quad (3)$$

$$S \{\text{select node } n_2\} = \text{MAX } \{D_1, D_2, \ldots, D_{i-1}\} // n_2 \text{ selected for path 2} \quad (4)$$

$$S \{\text{select node } n_3\} = \text{MAX } \{D_1, D_2, \ldots, D_{i-2}\} // n_3 \text{ selected for path 3} \quad (5)$$

Step 2:

$$n_1 \{\text{select node } n_{11}\} = \text{MAX } \{D_{11}, D_{12}, \ldots, D_{1i}\} // n_{11} \text{ selected for path 1} \quad (6)$$

$$n_2 \{\text{select node } n_{12}\} = \text{MAX } \{D_{21}, D_{22}, \ldots, D_{2(i-1)}\} // n_{12} \text{ selected for path 2} \quad (7)$$

$$n_3 \{\text{select node } n_{13}\} = \text{MAX } \{D_{31}, D_{32}, \ldots, D_{3(i-2)}\} // n_{13} \text{ selected for path 3} \quad (8)$$

Step 2 is repeated for n_i until destination *D* is reached, where, $i = 4, 5, \ldots, N$.

Algorithm (multi next hop selection):

1. For source node S
2. If (N_s! = NULL) //N_s denote neighbor nodes of Source node S
3. D_{sr} [i]←Neighbor distance
4. K←Total no of Path
5. For (i = 1, 2, 3 ………< = N_i)
6. B [i]←D_{sr} [i] //copy neighbor distance to another array
7. Sort D_{sr} [i]
8. For k number of path
9. D_{sr} [k]←k^{th} maximum distance.
10. Repeat step 13, 14 While (N [k]! = D)
11. N [k]←Queue $_{k\,//}$ store neighbor of k^{th} maximum distance in k^{th} Queue
12. L_k←L_k+D [k]
13. Count = count++//count is hop count
14. End if
15. Exit

Computation of path length: Nodes in ad hoc network are randomly distributed. We assume that the source and destination node does not often fall in transmission range of each other. Therefore, multi-hop paths are formed. We focus on establishing multi-hop multiple paths between source and destination node. Generally, path length depends on the position of intermediate nodes selected for routing messages from source to destination. But the position of intermediate nodes in the network does not always fall on the straight line between source and destination.

Therefore, path lengths vary from one path to another due to the varying position of intermediate nodes. We have proposed Eq. (9) to compute the path length between a source and destination:

$$L = \begin{cases} D_{sr}; if\ source\ and\ destination\ fall\ in\ same\ transmission\ range. \\ L_1;\ \sum_1^n d_{1i}\ ; sum\ of\ distances\ intermediate\ are\ nodes\ selected\ for\ path\ 1 \\ L_2; \sum_1^n d_{2i}\ ; sum\ of\ distances\ intermediate\ are\ nodes\ selected\ for\ path\ 2 \\ L_3; \sum_1^n d_{3i}\ ; sum\ of\ distances\ intermediate\ are\ nodes\ selected\ for\ path\ 3 \end{cases} \quad (9)$$

where, i = 1, 2, ..N. d_{1i} means distance of node 1 to its next node for path -1.d_{2i} means distance of node 2 to its next node for path-2 and so on. We have generalized the above Eq. (9) in (10) for k number of paths:

$$L = L_k;\ \text{where, } L_k = \sum_1^n d_{ri};\ r = 1, 2, 3\ldots, k \quad (10)$$

Computation of average number of hops: Hop count is also an important metric to evaluate the performance of ad hoc networks. Data delivered through smaller number of hops may increase network performance since it may reduce the delay in the network, if the links are uniformly congested. In case source and destination node fall in each other transmission range than hop count is 1. If the source and destination node are positioned in two opposite side of each other in the network and fall in straight line, minimum number of hop counts can be computed by using the following equation:

$$H_{min} = \left\lfloor \frac{D_{sr}}{R} \right\rfloor;\ \text{if an intermediate node fall exactly at R distance from its previous node} \quad (11)$$

But in ad hoc network the above scenario may exist rarely. Further, the average number of hops in the network for various paths can be computed by using Eq. (12) as given below:

$$H = \begin{cases} 1; if\ source\ and\ destination\ fall\ in\ the\ same\ transmission\ range, where, D_{sr} \le R. \\ H_1;\ Where, S \rightarrow\ n_{11} = 1, S \rightarrow n_{12} = 2 \ldots S \rightarrow\ n_{1i} = i; and\ D_{sr} > R\ ;\ hop\ count\ for\ path1 \\ H_2;\ Where, S \rightarrow\ n_{21} = 1, S \rightarrow n_{22} = 2\ \ldots S \rightarrow\ n_{2i} = i; and\ D_{sr} > R\ ;\ hop\ count\ for\ path2 \\ H_3;\ Where, S \rightarrow\ n_{31} = 1, S \rightarrow n_{32} = 2\ \ldots S \rightarrow\ n_{3i} = i; and\ D_{sr} > R\ ;\ hop\ count\ for\ path3 \end{cases} \quad (12)$$

We have generalized the above Eq. (12) in (13) for k number of paths:

$$H = \begin{cases} 0;\ where\ S\ != Ns = 0 \\ 1; when\ S\ and\ D\ are\ present\ each\ other\ range. \\ H_k;\ Where, S \rightarrow\ n_{k1} = 1, S \rightarrow n_{k2} = 2 \ldots S \rightarrow\ n_{ki} = i; and\ D_{sr} > R\ ;\ hop\ count\ for\ path \\ k; where\ k = 1,2,3, \ldots i \end{cases}$$

RESULTS AND DISCUSSION

For the result analysis we have computed path length for different paths and average number of hops between source and destination node. In our simulation, we have considered a random network and the position of source and destination node is not fixed in the network. The transmission range is taken as 250 m. The results are computed through MATLAB (http://www.mathworks.com).

Path length: Figure 2 shows the path length computation for different paths in the network. The path length count is minimum (i.e., 236 m) for path-3 when number of node is 10. For number of node 50 and 100, path-2 gives minimum path length. Further, path length count is increased by 69% in path-2 when number of nodes are 150. For path-1, path length gradually decreases when number of nodes varies from 30 to 50 but it increases beyond 50 nodes. Overall analysis shows that in both sparsely and densely populated networks path-length obtained for path-3 has minimum counts. But for intermediate or medium network topology path-2 is better.

Average number of hops: Figure 3 shows that the value of maximum hop count and minimum hop count is 6 and 2, respectively. From the results, it is clearly evident that source and destination nodes do not fall in the transmission range of each other. Initially for 10 nodes, hop count is small for path 3. For 50 nodes, path-1 and for 100 nodes path-3 have 6 hop counts. From the results, it is observed that for intermediate and densely populated network path-2 gives better results as compared to path 1 and 3.

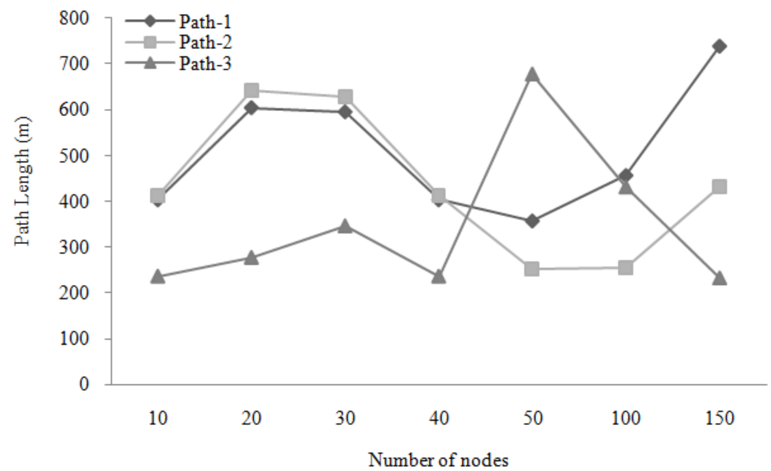

Fig. 2: Shows the path lengths of various paths with varying number of nodes

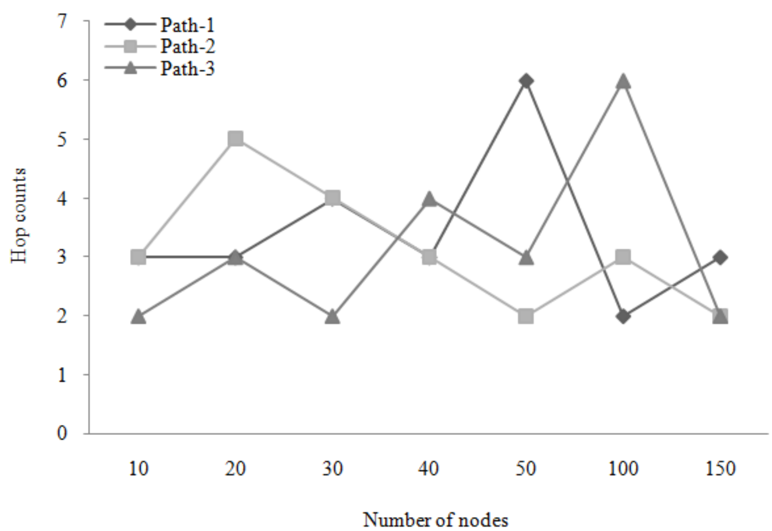

Fig. 3: Shows the average number of hops counts for various paths with varying number of nodes

CONCLUSION

We have designed and analyzed a multipath routing protocol for random network scenarios. In this protocol three different paths are established for data delivery from source node to destination node. Paths are established based on multi hop selection algorithm. The performance of the protocol is thoroughly analyzed and its behavior is studied for varying node density. We have computed path length and average hop count for analyzing the performance of this protocol. From the result analysis, it is clearly evident that path-2 gives better results as compared to path-1 and 3 in different network in term of path length and average hop count.

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