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Performance Betterments of Disjoint Paths in Designing an Efficient Multipath Routing in MANETs

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ABSTRACT: The efficiency of Mobile Ad hoc Networks (MANETs) is purely based upon the logical structure of multipath routing. Data communication between any two mobile nodes is established through a communication path formed by multipath routing. Multipath routing has been the backbone structure of MANETs because of its applications and advantages its provides to wireless communication networks. Multipath routing plays an important role, in the utilization of the available resources in a more efficient way, improving the efficiency of quality of services, providing security aspects to the communication network etc., in MANETs. But the strength, efficiency and capabilities of multipath routing are based upon various types of disjoint paths which have been the deciding factor of multipath routing in MANETs.

KEYWORDS: MANETs, Multipath routing, Partially disjoint paths, Disjoint paths, Edge-disjoint paths, Node-disjoint paths

I. INTRODUCTION

Multipath routing is needed for multi-hop communication systems. It is very clear that multipath routing is established between any two mobile nodes when they want to communicate with each other. At any time only one path will be executing even though there exist many paths between any two mobile nodes in MANETs. The data communication may be between two neighbouring nodes or very far located nodes. These two mobile nodes may be within the radius of a single communication domain or one node is in one mobile domain and another one is in another domain i.e., not within the range of mutual radii. In this case communication process will be established through intermediate nodes. i.e., if X and Y are two mobile nodes to communicate with each other in a MANET and they are in different communication ranges then direct communication is not possible between them, but communication is possible through other existing mobile nodes n_1 , n_2 , n_3 ,n_4.....n_k known as intermediate nodes between X and Y nodes. Then every intermediate node works as a router in the network. Thus node X sends data packets to node n_1, node n_1 sends data to node n_2 etc., and node n_{k-1} sends data to the last node n_k and the last intermediate node sends data to the node Y. This is the method of transferring data packets in a communication channel from the source node to the destination node through intermediate nodes.

Communication paths are to be established to send data from one node to another node and it is the responsibility of the source node to establish communication paths between mobile nodes and here again it is the source node which uses multipath routing techniques to establish paths. Various techniques are to be adopted by multipath routing to establish path connectivity such as Partially Disjoint Paths, Disjoint Paths, Edge-disjoint Paths and Node-disjoint paths. The path that is to be selected depends upon the existing situations of the network. These different path techniques exist when any failure in connectivity occurs between nodes. Connectivity failure occurs between nodes, when any mobile node suddenly moves out of the range of the network domain. Thus the existing path is suddenly disconnected and failure messages will be sent to the source node. Then the source node has to take appropriate steps regarding the establishment of new paths to bridge a connection between the disconnected nodes. This is the scope of various disjoint

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paths, which are mentioned above, where they can play a vital role in establishing connectivity between various mobile nodes in multipath routing. All these are discussed by the name of alternating paths in connecting various mobile nodes. Several multipath routing protocols are introduced to build multipath routing between nodes. But here the main focus is on disjoint paths which are the basic building blocks of multipath routing in MANETs.

II. LITERATURE SURVEY

Disjoint paths are independent paths in multipath routing protocols. Many algorithms are introduced to find disjoint paths. Two kinds of disjoint paths are existing in MANETs. i) Node-disjoint paths and ii) Edge-disjoint paths. In node-disjoint paths, paths do not have common nodes and in edge-disjoint paths, paths do not have common edges (excluding source and destination nodes). Node-disjoint paths are subsets of edge-disjoint paths so node-disjoint paths can also be regarded as edge-disjoint paths. In MANETs both nodes and connectivity links are capable of attracting errors. So node failures are common which can be happened by moving one or more nodes out of the network's range. But node failure can also be caused by very low battery energy. Data packets will be dropped during their transmission because of the sudden failure of communication links. Media access control can be another reason of link failures, which occurs when more mobile nodes try to share the common communication path for data transmission. Data decoding can also be a reason for node failure. If the data received at the destination node is not decoded properly then it may lead to link failure and link failure messages will be sent to the source node.

Establishing many disjoint paths between source and destination nodes is called edge-disjoint paths. In order to find a possible route between nodes, route query messages such as RREQ are used and transmitted by every node in the network to all other nodes of the network. Then an intermediate node receives only the first route request message and rejects all other duplicated messages thereafter. Thus all the remaining duplicate messages are dropped. The same process is adopted by all nodes of the network. The list of nodes that dropped duplicate messages are collected by a special technique called Diversity Injection. Again a list of nodes which received route request messages for the first time are also collected. Thus a path is created along the nodes which have received route messages for the first time. Thus edge-disjoint paths are created. Nodes at which route messages are dropped cannot be a part of edge-disjoint paths. As security measures are concerned both node-disjoint and edge-disjoint paths are safe but comparatively node-disjoint paths much safer than edge-disjoint paths. Diversity injection technique helps a lot to establish edge-joint paths in multipath routing.

Split Multipath Routing is another technique introduced to overcome the disadvantages of edge-disjoint routing. This technique forwards routing messages instead of dropping them. Intermediate nodes forward duplicate packets if the route request message comes from a different link other than the link from which the first route request is received. This technique reduces the difficulty of creating edge-disjoint paths in networks which paves an easy road to multipath routing. Thus diversity injection technique combining with split multipath routing collect the path information while distributing route request messages.

III. DISJOINT PATHS, NODE - DISJOINT PATHS AND EDGE - DISJOINT PATHS

To find various independent multipath routing protocols a special technique is introduced called Ad hoc On-demand Multipath Distance Vector Routing (AOMDV). It is an on-demand routing protocol based on distance vector routing. It is possible to compute multiple independent paths at each hop between source and destination nodes. This technique makes use of the information available in Split Multipath routing. AOMDV uses route request messages. The basic structure of AOMDV is based on AODV routing protocol. AOMDV distributes the route request messages in the same way as AODV protocol does. AOMDV retransmits all first route messages it received. For all other dropped messages instead of ignoring them, AOMDV collects all information contained in dropped route messages. This information is used for creating alternate route paths. These alternate paths are in addition to the existing routing paths. These paths preserve link-disjointness among all other paths which are connected back to the source node through an intermediate node which is created for this purpose. It can be called as reverse path routing which are used by intermediate nodes to send route messages back to the source node and these paths cannot be used by other nodes for their data transmission. AOMDV uses sequence numbers to every destination it uses. This method helps to make distinction between fresh nodes and old routes.

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AOMDV adopts many novel techniques to maintain multipath routing. Another technique it uses is advertised hop count which is used for maintaining multiple paths for the same sequence numbers it uses. The advertised hop count is set to the hop count of the longest path available at the time when a node first advertises a path for the destination. On each new sequence number it is reset until the sequence number changes. A route table is maintained at every node and contains information about the last hop for every path it finds. In this technique a path is found / formed from a node to its neighbouring node only if the neighbouring node has a smaller advertised hop count then the node itself. i.e., new path is found only on the basis of hop count from high to low. These path generation information is stored in route table of every node. During this path finding journey, paths have different first hops and different last hops which are disjoint. Comparing all other techniques AOMDV using advertised hop count with sequence numbers is a sophisticated method in generating new paths.

Node-disjoint paths have many applications in multipath routing. AODVM a multipath routing protocol is used to find node-disjoint paths. Here in this protocol, intermediate nodes are not permitted to send route request messages back to the source node. Thus intermediate nodes cannot transmit route messages. Instead of sending route messages back to the source intermediate nodes process alternate possible paths. Every node also maintains a route request table which maintains all information about its neighbouring nodes from which it received route request messages. It also calculates the cost incurred in receiving route requests from each of its neighbouring nodes. It is a cost effective method in which path finding is done on the basis of the cost incurred. When a route request message reaches its destination node, then the destination node sends a message to the last hop from which it gets the route request message. This message cannot go further as its next propagation will be decided by intermediate nodes. Here also every node maintains a node table which contains information about the contents the message has. Thus every information the received message is stored in this table. This technique provides the shortest path to the source node.

In AODVM nodes are allowed to participate in only one path formation process. If any node participates in multipath routing , then its neighbouring node does not listen to the node's transmission of a route request message. Thus the node deletes its neighbouring node in its table and does not give entry in its table to send route request message. So it never attempts a node in its new path finding process if the node already participates in another transmission. If any intermediate node receives route request message from its neighbouring node which is already participating in another transmission then the node's message cannot be forwarded further instead it sends route discovery error message to that node. Then that node tries to send the route request message to another neighbouring node to continue its transmission further. There is a limitation on the number of route discovery error messages that every node sends. This is a way avoiding unnecessary attempts to send transmissions to other nodes.

Prediction based link availability between nodes is another method of establishing links between nodes, which is useful in disjoint paths. Prediction based link availability algorithm is introduced. This algorithm guarantees the availability of link between two nodes continuously for a certain period of time. All these calculations are based on the movements of the current node. This algorithm may not calculate the exact and accurate availability of the link but it provides approximate chances of getting the link. This algorithm is useful to get an overall idea on link availability. Let the present node be n_k and also let n_{k+1} be its neighbouring node.

The chances of availability link can be calculated by prediction based link availability as follows :

Let the required time period be $Time_{period}$ and let Link availability be $L(Time_{period})$, then

$L(Time_{period}) = (Time_{mean}) / (Time_{period})$, where

$Time_{mean}$ = the mean time that a link will continuously available (actual time of availability)

$Time_{period}$ = The time that is needed for transmitting data packets from node n_k to node n_{k+1}

Prediction based link availability method always provides general approximations to the availability of link connection from the current node to another node. This method has one major drawback.

For any given time = T ,

required time of link availability = $Time_{period}$

then it cannot compute the continuous link availability from T to (T + $Time_{period}$)

This is the main disadvantage associated with this algorithm in its calculations for continuous link availability.

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The actual number of paths required for applying multipath routing depends upon the needs and requirements of the existing conditions from to time. Multipath routing is an effective and efficient way of generating paths in MANETs in order to overcome the disadvantages posed by single path routing techniques. The strength of multipath routing is based on the generation of paths which are based on node - disjoint paths, non - disjoint paths and edge-disjoint paths. These paths give the actual design and structure of multipath routing techniques. So many algorithms and protocols are introduced to find node-disjoint paths, non-disjoint paths and edge-disjoint paths. That is why disjoint sets are considering as the key and basic design in multipath routing techniques in MANETs.

IV. PERFORMANCE ANALYSIS OF DISJOINT PATHS

A source node in multipath routing receives route failure message only when all paths are failed. This link failure may be in many forms. If a link is failed between any two nodes of a given network (i.e., node moves out of the network) then it is enough to make connection between those two links but the source node may not identify this partial link failure instead it assumes that the link failure occurred between the node itself and the destination node. This is the case of majority networks as the network topology is highly dynamic in nature. This is the case where partial disjoint paths play a vital role. Here the partial disjoint may be either node-disjoint or edge-disjoint. In case of node-disjoint problem, searching is for a new node to which the new connection is to be established. That establishment is not from the source node to the destination node but only from the disconnected node to a newly established node. In most of the cases ,the entire establishment of new path is not needed. Thus work overhead at source node is reduced.
Thus energy resources of the source node are saved and these energy levels will be utilised to perform long network transactions in the network, otherwise the source node has to take the overall link establishment process for every link failure even though the link failure is between two neighbour nodes. Then performance betterments of the source node is improved which will result in the overall performance of the network. Thus it is very clear that disjoint paths play a vital role in designing an efficient multipath routing in MANETs. Because of its high dynamic nature, MANETs have many source nodes, in the sense, every intermediate node again acts a source node in directly. If energy level of most of the source nodes are saved then the overall energy time period available to the entire network is also increased and thus the performance ability and longevity of the network will also be increased which increases the reliability and Quality of Service (QoS) of the network. This indicates the overall performance betterments of disjoint paths in designing an efficient multipath routing in MANETs.

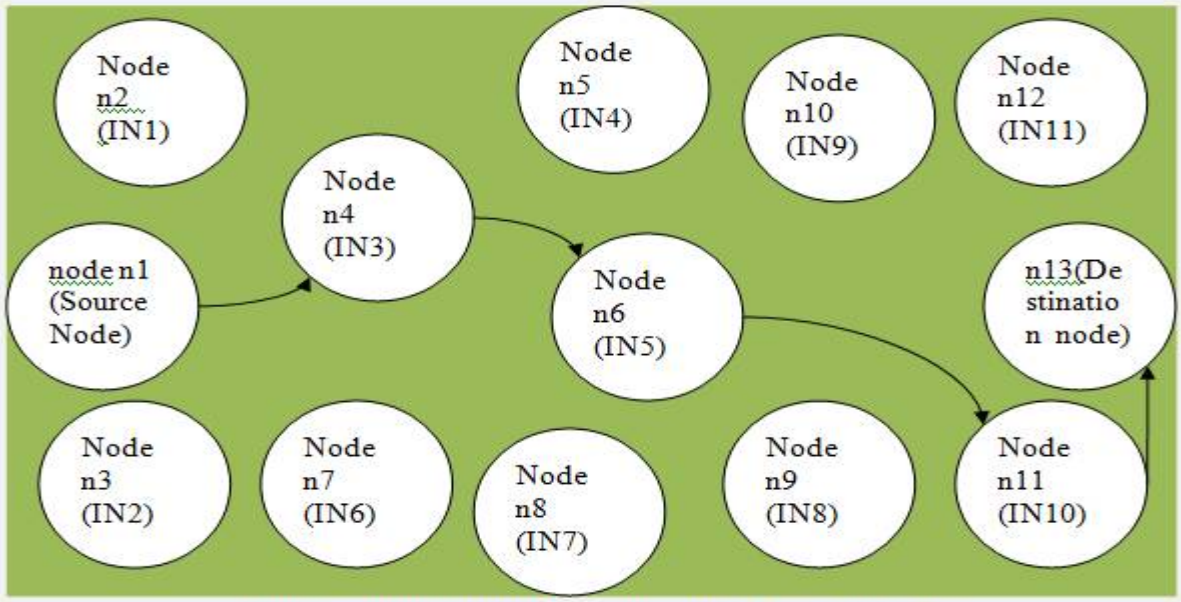

Figure 1: Multipath routing from source node to destination node

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In any given network, if data packets are to be sent from the source node, node 1, to the destination node, node 13 , as shown in the above Figure.1,then multipath routing establishes path along the nodes node 1 – node 4 – node 6 – node 11 – node 13. In the above figure IN indicates intermediate nodes. If link failure occurs at node 11, whatever reason it may be, then data packets can't be forwarded from node 6. It happens when the node 11 moves out of the mutual transmission range. The selection of routing among nodes is left to the source node as the source node decides which nodes are to be involved in data transmission. In this case a part of the entire path is vanished. This is the situation where disjoint paths take place.

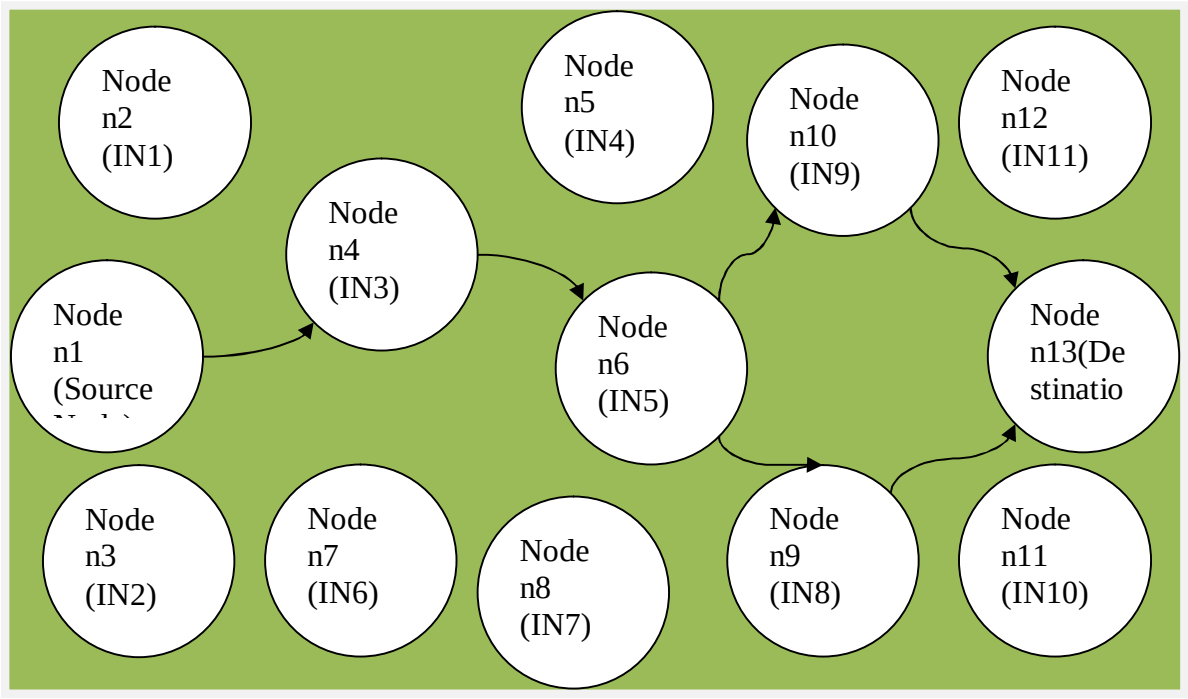

Figure 2: Possibilities of establishing partial paths for the disjoint node, node 11

As node 11 moves out of the domain of the transmission range, alternate paths are to be established immediately from node 6 as shown in the above Figure 2. Two possible paths can be established in this case i) node 6 – node 9 – node 13 ii) node 6 – node 10 – node 13. These two ways are shown in the above Figure 2. The selection of a particular partial path is more crucial here in this situation and is to be established without any time delay. Even though node 5 is an intermediate node, it acts as a source node, in directly, it plays vital role here. Selection of any particular partial path depends upon many factors (major and minor both), here the concentration is on major factors including the following:
i) The number of intermediate nodes existing (available) between node 5 and the destination node, node 13
ii) chances of nodes (node 9 and node 10) moving out of the domain, it is highly unpredictable but some ground level expectations are needed, which can be calculated on the basis of available power, bandwidth etc., as the network topology is, always, highly dynamic in nature i.e., changes rapidly as any node can move at any time.
iii) Efficiency of nodes, to carry out a particular given assignment, are based on the available energy or battery power, proper utilization of battery power, efficient usage of available limited resources, transmission power and transceiver capabilities of every node (as processing power and transceiver capabilities are differing from one node to another node) and the available bandwidth of the nodes (bandwidth also differs from node to node) participated in path establishment.
iv) Energy consumption of mobile nodes is very important in transmitting data packets from one node to another node. So energy consumption concept is to be considered for long lasting of the network existence. Many protocols are designed for energy consumption. A suitable one is to be selected among them.

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On the basis of the above analysis the performance betterments of disjoint paths in multipath routing is summarised in the following Table 1. The degree of performance of MANETs will be increased as the overall performance is improved. The following Table 1 gives a capsule of performance betterments.

Performance Betterments	Overhead on source node	Route error messages	Time takes to establish new links between nodes	Energy/ Battery	Long duration of the network	Transaction efficiency	Network performance	Efficiency even in rapidly changing nature of the network
Of Disjoint Paths in Multipath Routing in MANETs	is reduced, traffic is shared among all the available paths and load is balanced. It is applicable to all source nodes.	Minimised to a maximum extent. Disjoint paths help in reducing link failures.	Links are established at faster rates depending upon the routing protocols. Disjoint paths always try not to happen link failures	Energy is saved. Durability of mobile nodes is improved, transaction life is increased, nodes will not die for short periods.	Increased, works efficiently. All resources will be utilized effectively.	Improves. Link failures will be minimised. Probability of establishing paths will be nearly 1.	Overall performance is increased remarkably in all aspects of the network	Shows high efficiency ,even in highly changing dynamic environment too

Table 1: Performance betterments of disjoint paths in multipath routing in MANETs

V. CONCLUSION AND FUTURE WORK

More efficient and effective multipath routing and algorithms can be invented on the basis of various parameters involved in the designing of multipath routing protocols. To become more efficient protocols, factors such as node efficiency on the basis of their battery power, propagating capacity, resources utilization etc., should be taken into consideration. So energy factors of mobile nodes play a vital role in designing more energy efficient multipath routing techniques. This designing also takes bandwidth issues of mobile nodes into consideration which also play a major role in designing.

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