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Neighbor Non-correlated Routing Enhancement for Reducing Inter-Path Interference in MAN (NCCC-13)

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Abstract: In MANET whenever there is a need to send data packet from a source s to destination d, a route is discovered from s-d which usually consists of a shortest path. But use of such shortest path leads to congestion at the intermediate nodes causing a lot of packet drops. One solution to overcome this problem is load balancing. There are several techniques of load balancing proposed in Mobile Ad Hoc Networks. The methods are mainly based on finding multipath between a pair of source and destination nodes and finally splitting the traffic across the paths. The major issues of conventional multipath routings i.e. node, and link disjoint routings are that they present a lot of control overhead and are not really power saving due to lot of interference in the physical layer. Since nodes communicate through the shared wireless medium, the selected paths need to be as independent as possible in order to avoid transmissions from a node along one path interfering with transmissions on a different path. In this paper we propose a modified version of Adhoc On-Demand Distance Vector Multipath (AODVM) protocol called "Neighbor Non-correlated Multipath Routing" protocol. The main goal of "Neighbor Non-correlated Multipath Routing" is to reduce the interference among the constituent multipath which not only minimizes the control packets overhead but also ensures that the packet losses due to interferences are minimum. The technique is further compared with the other multipath routing techniques such as node and link disjoint multipath and the results are presented.

Keywords: MANET, Routing Algorithms, Multi-path Routing, Neighbor Non-correlated Multipath.

INTRODUCTION

Network topology changes too frequently. Moreover, the network topology may change again before the last topology updates are propagated to all intermediate nodes. Among the on-demand protocols, multi-path protocols have an ability to reduce the route discovery frequency than single path protocols [5]. On-demand multipath protocols discover multiple paths between the source and the destination in a single route discovery. So, a new route discovery is needed only when all these paths fail. In contrast, a single path protocol has to invoke new route discovery whenever the only path from the source to the destination fails.

Multi-path Routing can provide some benefits, such as load balancing, fault-tolerance, and higher aggregate bandwidth. Load balancing can be achieved by spreading the traffic along multiple routes; this can alleviate congestion and bottlenecks. From fault tolerance perspective, multi-path routing can provide route resilience. Since bandwidth may be limited in a wireless network, routing along a single path may not provide enough bandwidth for a connection, however, if multiple paths used simultaneously to route data, the aggregate of the paths may satisfy the bandwidth requirement of the application and a lower

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end-to-end delay may be achieved. Moreover, the frequency of route discovery is much lower if a node maintains multiple paths to destination.

The major problem with multipath routing such as node and link disjoint routings is that the paths are not completely independent. In fact, due to the medium access mechanism in wireless networks, such as CSMA/CA, data transmissions through these paths are not completely independent and each path will affect the other one. Thus, multi-path routing may not be a sound strategy if the constituent multiple paths suffer interference among themselves.

In this paper we propose a modified version of Adhoc On-Demand Distance Vector Multipath (AODVM) protocol called "Neighbor Non-correlated Multipath Routing" Protocol. The main goal of "Neighbor Non-correlated Multipath Routing" is to reduce the interference among the constituent multiple paths thereby minimizing the control packets overhead and number of packet drops and increasing the overall network throughput. The technique is further compared with the other multipath routing techniques such as node and link disjoint multipath.

The rest of the paper is organized as follows. The section II deals with the related works. Section III describes the proposed protocol mechanism in detail. Performance evaluation by simulation is presented in section IV. Simulation results and their analysis are given in section V and concluding remarks are made in section VI.

RELATED WORKS

Multi-path routing protocols proposed for ad hoc networks make use of the propagation of the RREQ messages along several paths to the destination and let the destination to send RREP along more than one path. The routing protocols avoid the RREP storm by selecting only few of the different paths.

Node disjoint multipath routing (NDMR) [6] is an extension of AODV protocol to discover multiple node-disjoint paths.This protocol is proposed to overcome shortcomings of on-demand unipath routing protocols like AODV & DSR. It has two novel aspects compared to other on-demand multipath protocols: it reduces routing overhead dramatically & achieves multiple node disjoint routing paths. This protocol achieves lower data delay & control overhead as well as higher packet delivery ratio than AODV & DSR.

Similar Node disjoint multipath routing (SNDMR) [7] modifies NDMR to select node-disjoint paths according to not only the entire route path but also similarity between the current path and the shortest path. This prevents the long paths from being selected as route. Routing using multiple paths similar to the shortest path will reduce the chances of out-of-order packet delivery and also result in lower end-to-end delay per packet.

The AODV-Multi-path (AODVM) routing protocol [8] is an extension of the AODV protocol to determine multiple node-disjoint routes. In this, an intermediate node does not discard duplicate RREQ packets and records them in a RREQ table. The destination responds with an RREP for each RREQ packet received. An intermediate node on receiving the RREP checks its RREQ table and forwards the packet to the neighbour that lies on the shortest path to the source. The neighbour entry is then removed from the RREQ table. Also, whenever a node hears a neighbour node forwarding the RREP packet, the node removes the entry for the neighbour node in its RREQ table.

Adhoc on demand multipath distance vector (AOMDV) routing protocol [9] is an extension of the AODV protocol to determine multiple link-disjoint routes. In this RREQs from different neighbors of the source are accepted at intermediate nodes and maximum hop count to each destination ("advertised hopcount") is used to avoid loops. Nodes maintain next-hop info for destinations (multiple next-hops possible). No complete route information known at a source.

In Split multi-path routing (SMR) [10], the intermediate nodes forward RREQs that are received along a different link and with a hop count not larger than the first received RREQ. The destination selects the route on which it received the first RREQ packet (which will be a shortest delay path), and then waits to receive more RREQs. The destination node then selects the path which is maximally disjoint from the shortest delay path. If more than one maximally disjoint path exists, the tie is broken by choosing the path with the shortest hop count. SMR uses per packet allocation scheme to distribute data packets in to multiple paths which prevents the congestion.

A quantitative comparison of multi-path routing protocols for mobile wireless ad hoc networks has been provided in [11]. In this, the advantages and the limitations of multipath versus single path routing has been examined and validated in general. In addition, they demonstrated that the establishment and maintenance of multiple routes result in protocol performance degradation. Furthermore, protocols with high routing overhead perform badly since the routing messages fill the queues and generate data packet losses. Finally they concluded that multi-path routing in general, distributes the traffic over uncongested links and, as a consequence, the data packets experience smaller buffering delays.

In [12] this author has proposed a Cluster-based Zone Multi-path Dynamic Source Routing (CZM-DSR) protocol. Here, an intermediate node upon receiving a RREQ message records the number of times it has seen the message in a locally maintained *ActiveNeighbourCount* variable in memory and broadcasts the message further if it has been seen for the first time. The destination node sends back a Route- Reply (RREP) message to the source node for every RREQ received. The path traced by the RREQ message is included in the RREP message. When an intermediate node receives the RREP message, it includes its *ActiveNeighbourCount* value in the message and forwards the message to the next hop node on the path towards the source. The source receives RREP messages through several paths and chooses the path whose maximum value for the *ActiveNeighbourCount* is the minimum. However, CZM-DSR will still incur a larger control message overhead and possibly a RREP-storm as the destination node would send a RREP message for every RREQ message received.

While determining a maximally zone-disjoint multi-path between a source-destination (*s*-*d*) pair, it is imperative to consider all the active routes (between every *s-d* pair) in the system rather than only considering the zone-disjoint paths between the particular source *s* and destination *d*. In [13], the authors have proposed a trial and error algorithm to determine two maximally zone-disjoint shortest paths between an *s-d* pair. The algorithm is based on determining an initial set of node-disjoint paths between the *s-d* pair and then iteratively discarding the *s-d* path that has the largest value for the hop count correlation factor with all of the other active routes in the system.

In [14], author has proposed a new zone-disjoint multi-path routing algorithm IZM-DSR. The proposed algorithm is very effective in decreasing routing overhead and also decreasing the end-to-end delay in MANETs. The algorithm, IZM-DSR does not need any RREQ_Query and RREQ_Query_Reply packet for finding the active neighbours. The RREQ_Seen tables in intermediate nodes have an extra field which name is 'Counter' to account the number of received RREQs. Each intermediate node that receives a RREP packet uses the count field in RREQ_Seen Table to update the activeneighborcount field. When a RREP receives to the source, the source waits for a certain time to receive all other RREPs. After that source can select some paths with less activeneighborcount field.

Zone-disjoint adhoc on demand multipath distance vector (ZD-AOMDV) [15], is an extension of the AODV protocol which determines multiple Zone-disjoint routes. In the proposed algorithm the concept of "Active Neighbor" is introduced. Active neighbors are the neighbor nodes which have already received and replied to the Route Request packet (RREQ) and it's probable that they exist on other paths for the same source and destination. so even though they are located on two disjoint paths they will still affect each other in simultaneous data transfer. The nodes in zone disjoint paths have almost no neighbor in the other path, to the feasible extent. In brief, proposed algorithm counts the number of active neighbors for each path from source to destination and eventually will choose paths that have the lowest total number of active neighbor nodes.

Since nodes communicate through the shared wireless medium, the selected paths need to be independent in order to avoid transmissions from a node along one path interfering with transmissions on a different path to ensure the least interference between the paths. Many metrics can be used to calculate the relative degree of independence among the multiple paths such as correlation and coupling factor [16]. The correlation factor, measured only for node-disjoint paths, indicates the total number of links connecting two node-disjoint paths. The coupling factor, measured for both node-disjoint and link-disjoint paths, is defined as the average number of nodes that are blocked from receiving data on one of the paths when a node in the other path is transmitting.

It has been observed earlier [17] that, larger the correlation factor between two node-disjoint paths, the larger will be the average end-to-end delay for both the paths and also the larger will be the difference in the end-to-end delay along the two paths.

In [18], the authors argue that, if two link-disjoint or node-disjoint routes are physically close enough to interfere with each other during data communication, the nodes in these multi-path routes may constantly contend for accessing the shared channel and the multi-path routing protocol may end up performing worse than any single path routing protocol.

In [19], author has focused mainly on two related problems: 1) the estimation of the throughput if only the interference of a single source-destination pair is considered; and 2) the impact of interference when multiple source-destination pairs are considered. They provided an evaluation of the throughput for a 2-path routing scheme while accounting for the interference of concurrent data transmissions for a given source-destination pair. Authors argue that benefits such as improvement in throughput and reduction in end-to-end delay obtained with multi-path routing become insignificant with respect to single path routing if we take into consideration the interference between the multiple paths and the cost of discovering these paths.

In [20], authors proposed a multipath routing scheme called Multipath On-demand Routing (MORT), in order to minimize the route break recovery overhead. This scheme provides multiple routes on the intermediate nodes on the primary path to destination along with source node. The primary path is the first path received by the source node after initiating the route discovery, which is usually the shortest path. Having multiple routes at the intermediate nodes of the primary path, avoid overhead of additional route discovery attempts, and reduce the route error transmitted during route break recovery.

PROPOSED ALGORITHM

Our proposed algorithm, called Neighbor Non-correlated Multipath Routing protocol, is an on demand multi-path routing protocol based on AODV.

Proposed Algorithm Procedure

The proposed system is based on the findings that as the numbers of neighbors grow in the network or as there are changes in the topology of the network, the overhead due to control packets such as Hello and RREQ packets also increases. In order to minimize this overhead we analyze the reachability criteria and suggest the same for all the multipath techniques.

When a node receives RREQ packet, or a Hello packet, it updates the neighbor table. When Hello packets are generated, each node sends the Id of its neighbors to its neighbors through Hello packet. Therefore in a network, all the nodes know the neighbors of their neighbors.

Interference occurs due to the fight for the slot of the channel by the neighbor nodes. Thus if the nodes which are commonly fighting for the slots are removed from the route then the interference automatically decreases, minimizing the packet losses. Based on this, we modify the RREP handling mechanism, in which intermediate nodes check if any other node which has forwarded the RREP packet has the same number of neighbors or not. If so it drops RREP, otherwise it forwards the RREP. Therefore in a pair of source and destination, there exist no two nodes whose neighbors are common. In this way obtained paths are non-correlated in terms of channel sharing nodes are concerned. In figure 1, after completion of route discovery process, the neighbor non-correlated paths discovered are <0->2->6->7>, <0->5->6->7>, <0->5->3->7>, <0->1->3->7>, <0->1->6->7>, <0->2->4->7>, <0->5->4->7>.

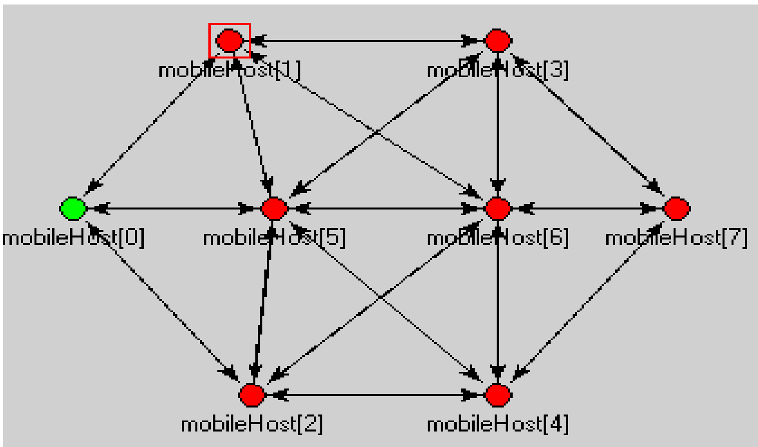

Figure 1: Discovering multiple paths during route discovery

Pseudo code of Neighbor Non-correlated Multipath Routing Protocol

The steps taken by source node, destination node and intermediate nodes are listed in figures 2, 3 and 4 respectively.

1. If there is data to be sent to a certain destination and there is no valid path for that destination, broadcast the RREQ packet.
2. Wait for first RREP packet to arrive.
3. After receiving the first RREP packet, wait for a certain amount of time to receive other RREPs, then start load balancing data transfer on these paths.

Figure 2: Pseudo code for the source node in Neighbor Non- correlated Multipath Routing

1. Send back a RREP packet to all the nodes from which a RREQ packet is received.

Figure 3: Pseudo code for the destination node in Neighbor Non- correlated Multipath Routing

1. On receiving RREQ, inform all other neighbor nodes about the nodes from which it received RREQ by appending node IDs in Hello Packet
2. Once the RREP message is received, check if any other Node in any other path selected between current source and destination, has same number of Neighbors or not
3. If so drop the RREP, otherwise send back the RREP in reverse path towards the source node.

Figure 4: Pseudo code for the intermediate node in Neighbor Non- correlated Multipath Routing

PERFORMANCE EVALUATION

In order to evaluate Neighbor Non-correlated Multipath Routing, we have compared its performance to node and link disjoint multipath with regards to several performance metrics.

Simulation Environment

We have used OMNeT++ as the simulation environment. Our simulation environment consists of N number of mobile nodes in a region of size 1000m x 1000m.The nodes are randomly placed in the region and each of them has a radio propagation range of 100 meters. We have used Free Space model as the radio model to transmit and receive packets.

The IEEE 802.11 is used as the medium access control protocol. We use the Random Waypoint mobility model, one of the most widely used models for simulating mobility in MANETs. According to this model, each node starts moving from an arbitrary location to a randomly selected destination with a randomly chosen speed in the range [minimum ... maximum].

Once the destination is reached, the node stays there for a pause time and then continues to move to another randomly selected destination with a different speed. The size of the data packets are 512 Bytes. Each simulation is run for 200 seconds.

Performance Metrics

We use following performance metrics in order to evaluate performance of the proposed protocol.

Packet Delivery Ratio: It is defined as the ratio of number of packets sent by source to the number of packets received by destination.

Throughput: Throughput is the measure of number of packets passing through the network in a unit of time i.e. the average rate of successful message delivery over a communication channel. The throughput is usually measured in bits per second.

Latency: The time interval between the transmission of the packet by a source node and the reception at the destination.

Control overhead: It is defined as number of control packets transmitted for every data packet delivered.

Average Number of paths/sec: It is the Average number of paths generated per second during entire simulation time.

SIMULATION RESULTS AND ANALYSIS

In order to evaluate performance of the Neighbor Non-Correlated multipath routing scheme and compare with other routing schemes such as node-disjoint and link-disjoint multipath routing in different network conditions, three scenarios are considered.

Scenario – I: Varying Number of nodes: In this scenario, mobility is kept constant at a speed of 5 m/s, a pause time of 150s and a rate of 20 packets/s/session. Simulation is carried out by varying number of nodes from 10 to 70.

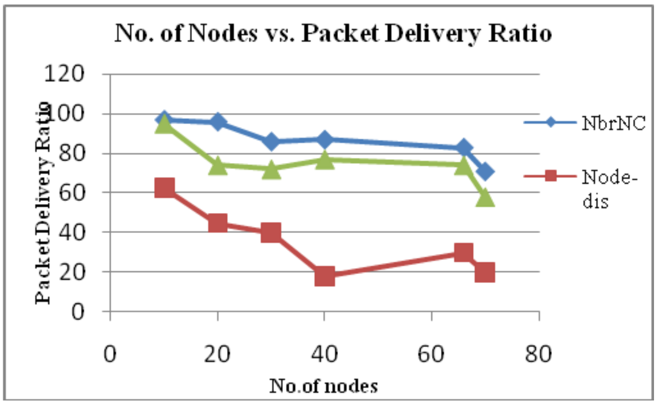

Fig. 5: Variation of Packet Delivery Ratio with network size

Figure 5 shows the Packet delivery ratio comparison of Neighbor non-correlated multipath with node-disjoint and link-disjoint multipath. Packet delivery capacity of all these routing techniques decreases as the number of nodes in the network increases. This is due to the increasing number of route breaks as the size of network increases. However, the proposed scheme outperforms node and link-disjoint routing schemes in packet delivery capability for all sizes of network. This is due to the selection of neighbor non-correlated paths which reduces the interference among constituent multiple paths. This reduces number of packet drops and increases packet delivery ratio.

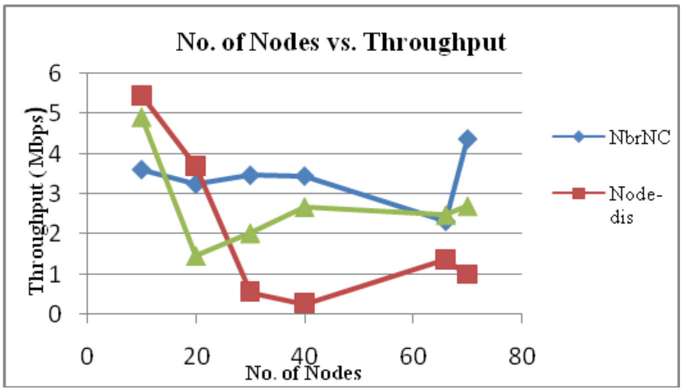

Fig. 6: Variation of throughput with network size

In figure 6 we observe that the throughput of the proposed protocol is better than the Node and Link-disjoint protocols for all sizes of network. This is because in Node-disjoint and Link-disjoint multipath interference is more compared to Neighbor non-correlated multipath, which leads to more packet drops.

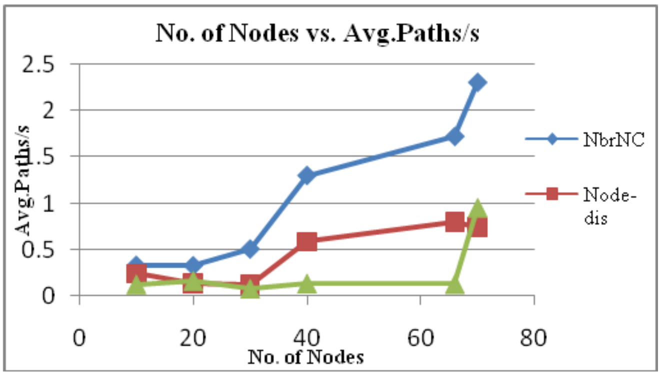

Fig. 7: Variation of Avg.Paths/s with network size

In figure 7 it is shown that as the network size increases, average number of paths generated per second is more for our proposed protocol 'Neighbor non-correlated multipath' compared to Node-disjoint and Link-disjoint protocols during entire simulation.

In figure 8 we observe that as the network size increases, the latency also increases for our proposed protocol compared to Node-disjoint and Link-disjoint protocols. This is because 'Neighbor non-correlated multipath' protocol takes more time to discover the routes as each intermediate node on receiving a RREP packet has to check its neighbor table to see if any other node in any other path selected between current source and destination has same neighbors or not.

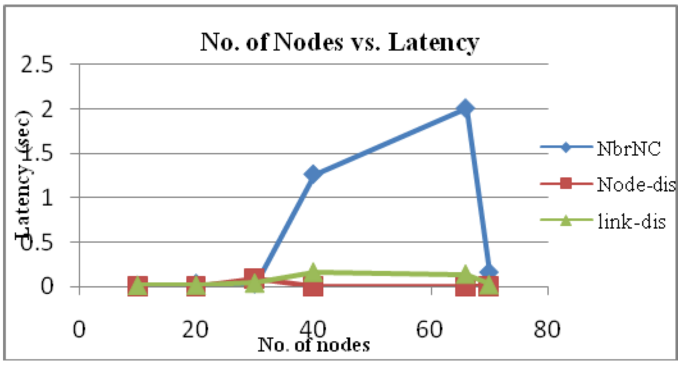

Fig. 8: Variation of Latency with network size

Scenario – II: Varying the network Load: In this scenario, mobility is kept constant at a speed of 5 m/s, pause time is set to 150s and the number of nodes to 30 nodes, and simulation is carried out by varying load from 10 to 80 packets/s/session.

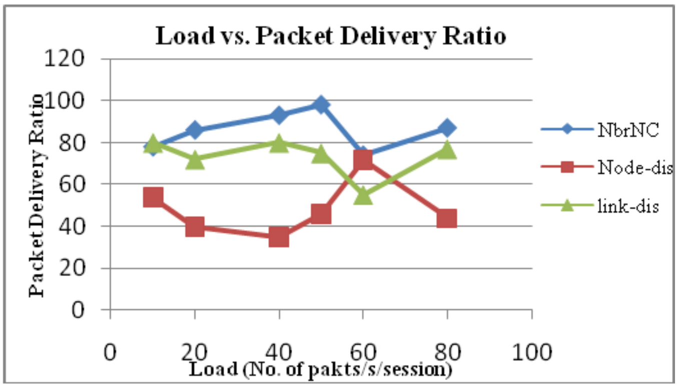

Fig. 9: Variation of packet delivery ratio with network load

In figure 9 it is observed that the packet delivery ratio has been improved in the proposed scheme by varying network load. At higher loads, number of false route breaks increases due to the congestion created by increased data packet sending rate. False route breaks occur as nodes falsely assume that a route break has occurred when there are lots of packet drops due to the collisions created by congestion. At higher loads, the proposed scheme shows better performance than node and link-disjoint multipath protocols. In figure 10 we observe that the Control Overhead of the proposed Neighbor non-correlated multipath protocol is very low compared to node and link-disjoint protocols. This is because in the proposed protocol interference is very low which reduces the number of packet drops, thereby reducing the number of control packets compared to other two protocols.

From the figure 11 it is clear that as the network load increases, the latency also increases for the proposed protocol compared to Node-disjoint and Link-disjoint protocols. This is because as the load is increased there may be a possibility of more packet drops due to the congestion which leads to more false route breaks which occurs as nodes falsely assume that a route break has occurred when there are lots of packet drops. So it initiates fresh route discovery if no more paths are available. As discussed already, for our proposed scheme route discovery time is more than other two protocols. So the latency is also high for this scheme.

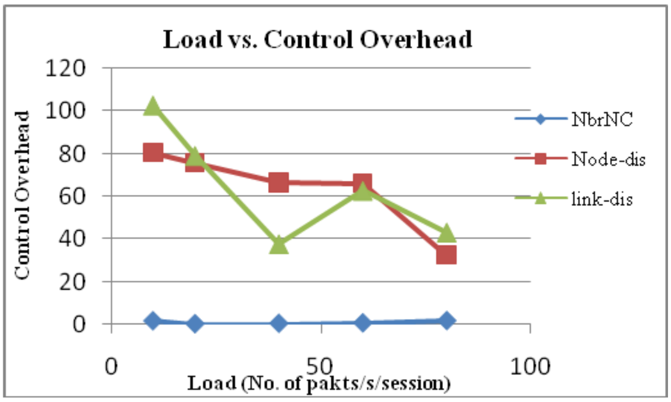

Fig. 10: Variation of Control Overhead with network load

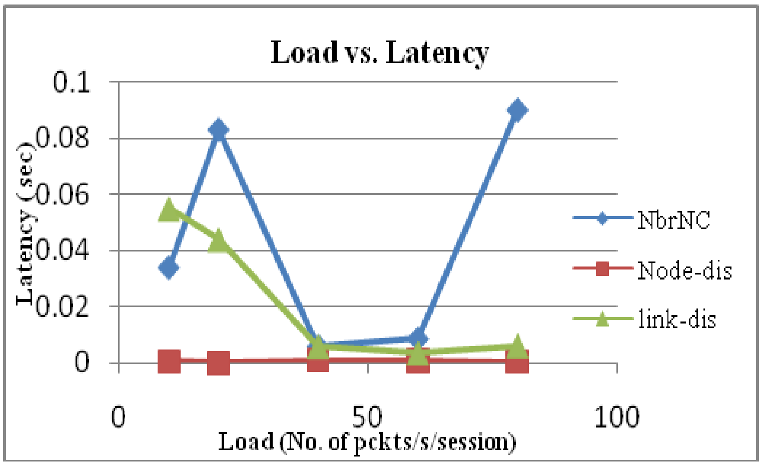

Fig. 11: Variation of Latency with network load

Scenario – III: Varying Pause time: In the third scenario, we vary pause time by keeping number of nodes, rate and speed of the node at a constant values 30, 20pkts/s/session and 5 m/s respectively. Simulation is carried out by varying pause time from 10 to 150 seconds.

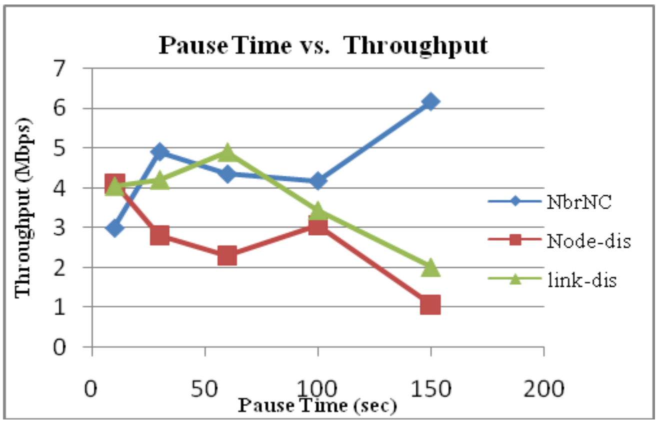

Fig. 12: Variation of throughput with Pause Time

In the figure 12 observe that as the pause time increases, the throughput of proposed protocol increases where as throughput of node and link-disjoint multipath protocols decreases. So, our proposed protocol achieves better throughput compared to node and link-disjoint multipath protocols since the proposed scheme reduces the interference among the constituent multipath which minimizes number of packet drops.

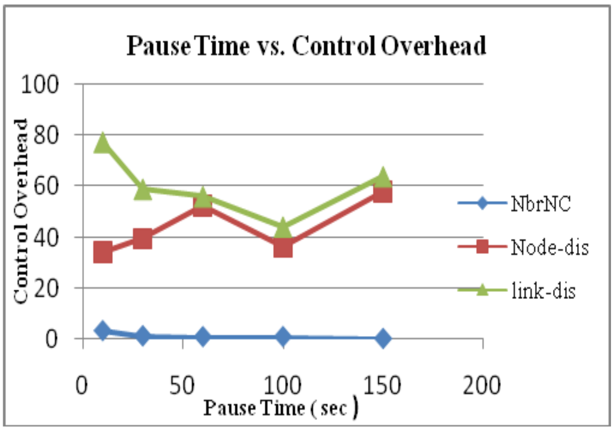

Fig. 13: Variation of Control Overhead with Pause Time

In this figure 13 we observe that the Control Overhead of Neighbor non-correlated multipath protocol is significantly low compared to node and link-disjoint protocols. This is because the proposed protocol decreases the number of route discovery process and also in this protocol interference is very low which reduces the number of packet drops, thereby reducing the number of control packets compared to other two protocols.

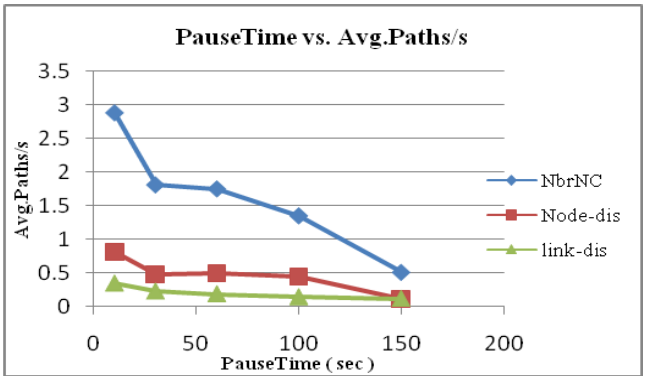

Fig. 14: Variation of Avg.Paths/s with Pause Time

In the figure 14 observe that as the pause time increases, Average number of paths generated per second decreases for all the three routing protocols. For the proposed scheme, at low pause time Average number of paths generated per second are more and at higher pause time this value decreases. But as the pause time varies, proposed protocol shows better performance than the node and link disjoint protocols during entire simulation.

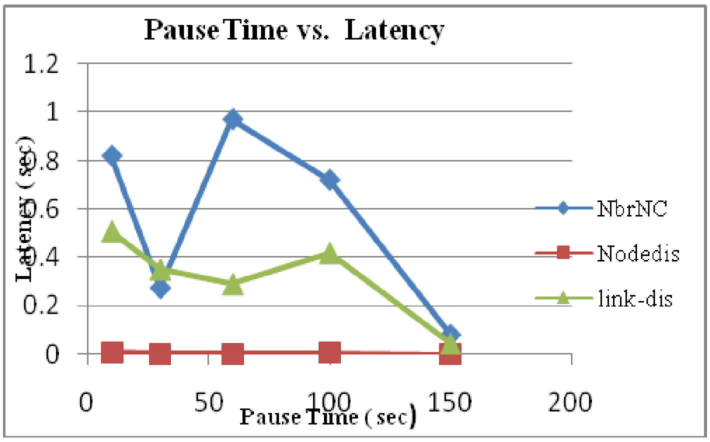

Fig. 15: Variation of Latency with Pause Time

As we have observed, the latency of the proposed protocol 'Neighbor non-correlated multipath' is higher than the node and link-disjoint protocols in all the scenario. In this scenario also latency is high at low pause time, but as the pause time increases latency of the proposed protocol decreases as shown in figure 15. This is because as the pause time increases mobility of the nodes decreases, reducing the frequent path breaks which inturn reduces frequent route discoveries resulting in lower latency.

CONCLUSION

In Mobile Ad hoc networks the major issues of conventional multipath routings such as node and link disjoint routings are that the constituent multiple paths suffer interference among themselves. Since nodes communicate through the shared wireless medium, the selected paths need to be as independent as possible in order to avoid interference during data transferring phase. In this work we proposed a "Neighbor Non-correlated Multipath" routing in which the nodes which are commonly fighting for the channel slots are removed from the route, thereby reducing the interference. For evaluating our suggested protocol we compared it with node-disjoint and link-disjoint multipath routing protocols. Simulation results show that the Neighbor Non-correlated Multipath routing protocol has a better performance than the node and link-disjoint multipath routing protocols in improving packet delivery ratio, throughput, control overhead and number of paths generated per second. Our future work would involve further development of the protocol for quality of service. Another possible modification of the proposed model can be analyzing the energy consumption aspect and studying its effect on node life time.

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