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Maximizing the Network Life Time Based on Energy Efficient Routing in Ad Hoc Networks

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Abstract The maximization of a networks lifetime is an important part of research in the present scenario. In an ad hoc network, the topology of network changes frequently due to the mobility of mobile nodes where the communication is possible without any network infrastructure. Mobile nodes have limited energy resources so that the energy efficient routing should be provided which increases the life time of the network. The existing routing mechanisms do not consider energy of nodes for data transmission. In this paper the data transfer from source to destination is based on the minimum hop count and residual energy of the mobile nodes. The analysis is carried out by using the network simulator. The simulation results shows that the proposed work provides an energy efficient routing in ad hoc networks.

Keywords Ad hoc networks · Residual energy · Energy efficient routing · Network life time

1 Introduction

In ad hoc networks, the operations of nodes are based on the transmission range and battery power. Each node on the networks performs routing operations which provides the communication between different nodes. All nodes in the network can transmit their data to their intermediate nodes or to the destination, if it has enough energy and the nodes are within the transmission range. If the mobile node does not have the energy it cannot

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transmit the data or participate in the network operation. So node energy consumption should be provided for efficient data transmission. The network liftime can be increased by using energy efficient routing mechanism in multi hop networks for data transfer. The extension of battery life time of node improves the nodal energy which increases the network performances. The mobile nodes in ad hoc networks are self-managed where they can work in remote areas without any maintenance or repair. Usually the data transfer from source to sink is carried out by using multiple hops where minimum energy consumption should be provided per packet transfer between the intermediate nodes which results in a reduction of total expenditure of energy per packet transmission. The death of mobile nodes in the ad hoc networks will adversely affect services. Figure 1 shows multi hop data transmission where the source will send route request to all the nodes participating in the network, when the request reaches the destination it will send route reply along with acknowledgement.

The mobile nodes will dissipate energy when data's are transmitted or received by the nodes. In multi hop transmission, the data from source to sink is reached through different intermediate nodes by considering the route request and route reply. The route request (RREQ) is sent by the source to the destination as to whether it will have free routes for data transmission for providing multi hop communication [1] from source to destination. The destination will send a route reply (RREP) to the source which will have the information whether a free route is available or not. Based on the RREP the source will find a route with minimum hop count. The above multi hop communication only four hops are required for the data from source to reach destination. Here the source will send the data to node 1–node2–node3 and finally to the destination.

Minimum number of hops from source to destination will decrease the time delay which improves the network performances.

The mobile nodes in ad hoc networks can be function as both the data router and data originator, if some nodes does not have enough energy there may occur changes in topology which reorganize the network, necessitating data to be rerouted and resulting in high energy consumption, calling for more energy from other nodes and causing decrease in network life time. By considering the residual energy for data transfer, the network life time can be improved. The residual energy is the energy left out in a node after transmitting or receiving the packets. If this energy is less, the node may die out of energy starvation and cannot participate in routing process. In order to avoid this problem nodes having maximum residual energy [2] are considered for data transfer that decreases the death of nodes in network so that the network life time can be improved. Thus, the methodology in this paper can be summarized as calculate the number of packet which should reach the

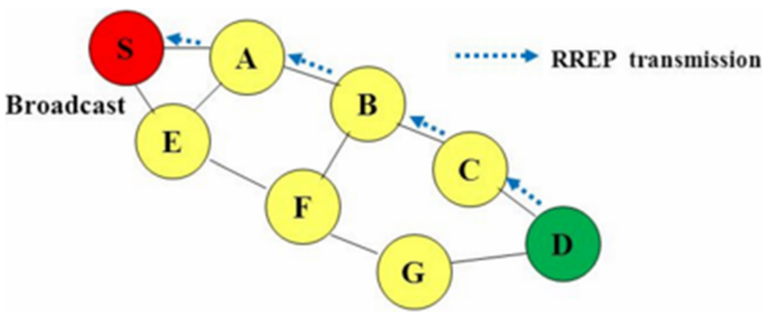

Fig. 1 Multi hop communication

destination, Insert the values in the list and after route request and route reply consider an energy efficient path for data transfer based on hop count and residual energy.

2 Related Work

In this section, some existing protocols are reviewed and the importance of energy efficient routing in ad hoc networks is over viewed. An energy aware routing such as Reliable Minimum Energy Cost Routing (RMECR) [2] and Reliable Minimum Energy Routing (RMER) [2] provide energy efficiency and reliable routing. RMECR and RMER ensure the reliability by providing hop by hop communication and end to end retransmissions. The centralized algorithm [3] Basic Algorithm for Minimum Energy Routing (BAMER) and General Algorithm for Minimum Energy Routing (GAMER) solves the minimum energy communication problem for unreliable links whereas Distributed Algorithm for Minimum Energy Routing (DAMER), approximates the centralized algorithm which improves the performance over single or multipath techniques. The Expected Transmission Count Metric (ETX) [1] finds an high throughput path for multi hop wireless networks. ETX minimizes the total number of packet retransmissions since all the packets sent by the source are successfully delivered to the destination. ETX as metric are designed and implemented in DSDV and DSR routing protocol for improving the network performances. ETX will be significant for large networks and for longer paths.

Power Aware Protocol with Signaling for Ad Hoc Networks (PAMAS) [4] provides a power conservation by turning off radios under certain network conditions thus Power saving is achieved without affecting the network performances such as throughput, delay of basic routing protocol. Power Aware Routing in mobile ad hoc networks (PARO) [5] can be implemented in existing routing protocol which provides a routing that consumes the node power and also maintains a shortest cost routing for data transfer from source to destination.

The problem of Disjoint Connecting Path (DCP) [6] should be avoided in order to improve the network life time. On line Maximum Life Time Heuristic (OML) [6] improves the life time by depleting the sensor energy to a certain level below that the transmission is carried out by its closest neighbor. This protocol provides a larger network capacity and maximizes the life time. Minimum Drain Rate (MDR) [7] improves the battery life of mobile nodes and extends path duration whereas Conditional Minimum Drain Rate (CMDR) [7] reduces the transmission power consumed per packet. Drain rate calculates the energy dissipation rate of a node. Drain rate value of a node determines that whether it can participate in the active route for data transmission.

Ad hoc networks have a limited battery resources so power consumption should be provided in order to prolong the network life time. Battery power capacity and the required, transmission power should be considered for providing an efficient routing mechanism. Conditional MaxMin Battery Capacity Routing (CMMBCR) [8] scheme provides data transmission through the shortest path if all nodes have enough battery capacity. When the battery capacity of some nodes decreases below a threshold level, these nodes are avoided for data transmission which extends the power down time of the first node.

Minimum Battery Cost Routing (MBCR) [9] algorithm chooses a route which minimizes the battery cost function. The disadvantage of MBCR is that the route selection is only based on the battery cost which may lead to overuse of a particular node that in turn decreases the network life time. Min–Max Battery Cost Routing (MMBCR) [9] algorithm chooses a route with maximum values of minimum residual energy. Here the longer path, for data transfer, is used since the cost of the path which consumes more energy was not considered.

Maximum Residual Packet Capacity (MRPC) [10] selects a path having largest packet at critical node. MRPC can be easily implemented in various ad hoc protocols. In Conditional CMRPC [10] algorithm if the forwarding capacity of a node falls below the threshold value, it switches to MRPC. By using MRPC the life time of a network can be extended and also packets can be transmitted with high energy efficiency. Data Centric [11], Location Based [11] and Hierarchical [11] based routing provides an efficient data flow and quality of services. Based on the route discovery and route reply from source and destination, shortest path is used for data transmission. Intra cluster routing [12] provides an energy saving routing mechanism. Parameters evaluated for the improvement of network performances are variety of packets sent within the network, energy consumed by the network, remaining energy state of node at specific time, and network lifespan. Intra cluster coverage improves the network performances.

Multi hop Wireless Mesh Network (WMN) [13] have different access points, mesh routers and number of mobile nodes. The quality of link in the network is analyzed where the high quality link is used for data transmission which avoids the link failure during the data transmission. Energy consumption routing models [14] are used for improving the quality of services. Node energy is one of the major constraints which decide the performance of ad hoc networks. If the node does not have sufficient energy for forwarding data, it cannot participate in the routing process. Usually the data transfer will be carried out based on the hop count from source to destination. So if a path has minimum hops it is used for the data transmission. But the continuous transmission of data through the same path decreases the node energy which degrades the network performances. Thus efficient energy consumption should be provided which increases the network life time so that an improvement in network performances can be obtained.

3 System Model

3.1 Network Model

The ad hoc networks mainly consist of different mobile nodes, a set of base station and trusted party. The nodes are distinguished by their mobility, processing time, energy consumption and memory capacity. All nodes in ad hoc networks have limited battery power, so node energy consumption is very essential. Hence power efficient energy aware routing protocol is implemented. Here the data transmission from source to sink is carried out depending on the minimum hop count and the residual energy of each node. When the energy level of the node decreases to a certain level it will intimate the source and source will find an alternate path for data transmission. Hence by providing an energy efficient routing, life time of the network can be improved.

3.2 Adversary Model

The mobile nodes in ad hoc networks are self-managed connected by wireless links. An attacker in the network can easily drop the communication between the nodes or can also alter the node operations. The intruder will try to enter in the network and destroy the operation carried out between the nodes. So in order to provide an efficient data transmission, the attacks in the network should be avoided which is provided by using cryptographic operations.

4 Proposed Routing Procedure

In conventional routing mechanism, the intermediate node energy level is calculated by source only. So only the source will be able to know about the energy levels of intermediate nodes, so the chance of data transfer through the same path is high, if the data's are transmitting through the same path, network life time will decrease since same nodes are used for data transfer from source to sink resulting in the death of these nodes occurs due to the lack of energy. So in the proposed routing mechanism, the change of path for data transfer is carried out, if the energy level of node decreases to a certain level, so that the death of node can be decreased which in turn improves the network life time. The data transmission from source to sink node is carried out by considering the residual energy and hop count. The node having maximum residual energy [2] is considered for data transfer.

Figure 2 shows an example of proposed routing mechanism carried out in a network. Here the data from source node to sink node can be transmitted through two different routes. The first route (S-3-4-5-D) has three nodes with residual energy 2, 3, 6 respectively and second route (S-1-2-D) has two nodes having residual energy 5 and 3 respectively. From these two routes, second routing mechanism is preferred for data transfer from source to sink nodes because it has minimum hop count with maximum residual node. Even though, first rout will have the highest residual energy (5) it is not considered for data transfer since the hop count for this route is high compared to the other one which improves the time delay which adversely affect the network performances. Hence the proposed routing mechanism considers both the hop count and the residual energy for data transfer thus improving network life time.

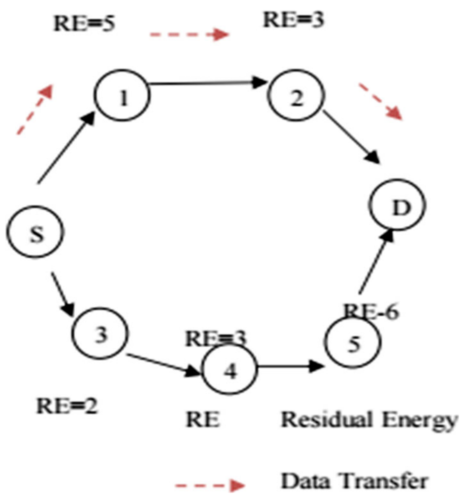

Fig. 2 Example for proposed routing mechanism

5 Energy Efficient Data Transmission

Energy is one of the important parameters that decide the performance of ad hoc network. The mobile nodes may run out of battery if same nodes are used for the data transfer from source to destination. Usually the data from source to destination will consider only minimum hop count while not considering the node energy. In order to improve the network performance, energy efficient routing is considered where the data transfer from source to destination will depend on the residual energy of the node. Residual Energy of a node depends up on the amount of data transmitted or received by the node which can be calculated as, Residual Energy = Initial Energy of a node remaining energy of node after transmitting the data at time t (1). Initially all the nodes participating in the network will have equal energy, after transmitting the data through the nodes, node energy decreases which reduces the network life time. So in order to improve the network life time [6, 10], the nodes participating in the network will inform the source to change the path, if its residual energy is less than a threshold value.

The routing protocol should function effectively under different network conditions and which should consumes minimum node energy consumption. Power efficient energy aware routing protocol is implemented for providing the data transmission based on the residual energy and minimum hop count. The function of the protocol comprises of route discovery, routing table and route maintenance.

5.1 Route Discovery

Different routes from source to destination can be obtained by sending a route request (RREQ) from source to nodes participating in the network. When RREQ reaches the destination, it will send route reply (RREP) back to the source. Here the nodes with minimum hop count and having highest residual energy are considered for data transfer from source node to sink node.

5.2 Routing Table

Routing Table will contain all the details of the mobile nodes, its neighboring nodes, hop count, residual energy. Based on the values on the routing table efficient mobile nodes are considered for data transfer. If the residual energy of the nodes decreases to a certain level it will intimate the source to find an alternate path for data transfer. Depending up on the values in the routing table, the source will find an alternate path for data transmission from source to destination.

5.3 Route Maintenance

The route established from source to destination should be maintained under different environmental conditions. The route is maintained by sending the route error (RERR) messages. While transferring of data if any problem occurs, the intermediate node will send RERR messages to the source so that it can find an alternate path for data transmission.

6 Proposed Module Descriptions

Different modules are considered by the proposed routing protocol for providing efficient data transmission and improving the network performances. The different modules are (a) Calculate number of packets Number of packets is calculated, based on the transmission and retransmissions of packets and the energy of each node is evaluated. (b) Insert the values to routing list After initialization of the list, various data about the nodes and routes are stored. (c) Path Selection whenever a node will try to send a data it initially sends route request messages which contain packet type, source id, destination id, and the packet number. Based on this information, the intermediate node will check the destination id if it matches it will check about the source information. If it is already available it will check which is the better path based on the hop count and residual energy, if a new path is found better it will generate RREP and send the data through that path otherwise it will stick to the old one. If the destination id does not matched it will store that value in the list and forward it to neighbors for next process. (d) Residual Routing When intermediate node gets troubled, it will send request to the source, then the source will consider an alternate path for data transfer. If the nodes are not troubled, source will automatically select an alternate path when node energy is low.

7 Performance Evaluation

The performances of energy efficient routing based on node residual energy are simulated by using network simulator 2 software. Results can be obtained by in the form of trace analysis, Network animator (NAM) window and XY graph. Trace analysis shows the packet trace on individual link. The data transmissions from source to destination through non traceable nodes are analyzed by using NAM window. Figure 3 shows the output in NAM window where the data transmission from source to destination is based on the residual energy of nodes.

Performance metrics can be used to evaluate the network performances by considering different parameters.

7.1 Overhead

Overhead is one of the important parameter which may inversely affect the network performance. The increase in overhead degrades the network performances. Overhead is the additional data's attached to the original information. If overhead is large, the data from source will take more time to reach the destination which adversely affects the network performance. Figure 4 shows the overhead comparison between the conventional and proposed routing mechanism. Redline in the graph shows the overhead in conventional routing whereas green line shows the proposed routing. The overhead in network may occur due to the excess computation time, memory or bandwidth. In order to improve the network performance, the overhead should be less. From the below graph below we can conclude that the proposed routing mechanism reduces the overhead which increases the data transmission rate.

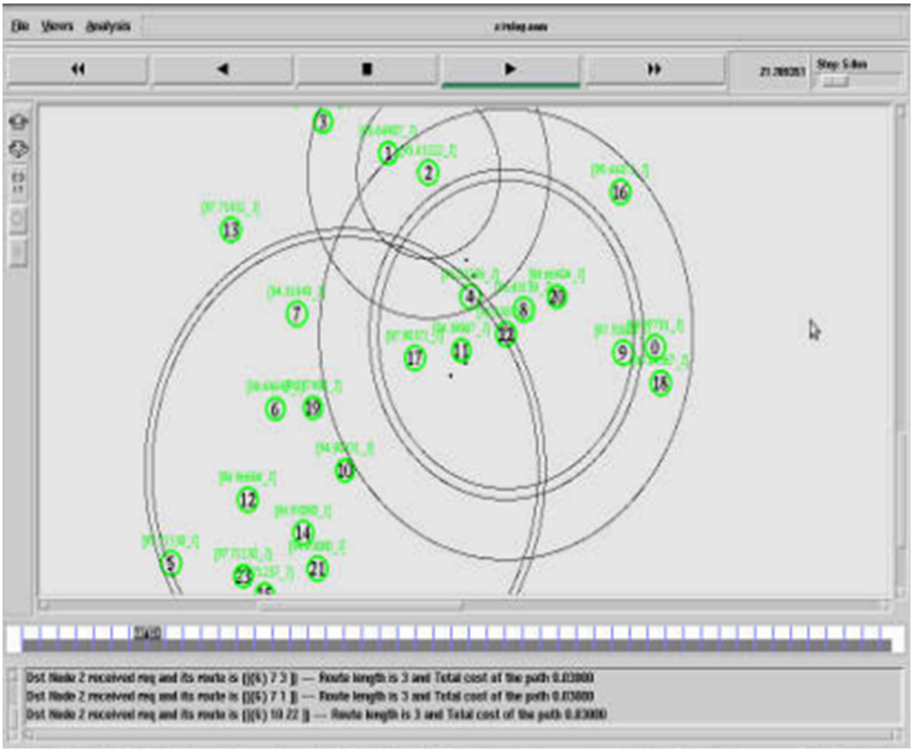

Fig. 3 Simulation window showing data transmission between intermediate nodes

7.2 Delay

Delay is the time taken or the data to reach the destination. Delay should be less for improving the network performance so that the data can reach the destination with minimum time. Figure 5 shows the delay for the proposed mechanism is less because if the intermediate nodes have any problem it will find an alternate path for data transfer which decreases the delay.

Energy Consumption Energy consumption of a node is the total energy consumed by a node to transfer the data. Energy consumption and network performances are inversely related to each other. In order to provide energy efficient routing, the node should use minimum energy for transferring the data to the destination. Figure 6 shows the comparison of the energy consumed by the node in proposed and conventional routing mechanism. The red line indicates the conventional routing whereas the green line shows the proposed mechanism. In conventional routing mechanism, node energy was not considered for data transmission, only the hop count was considered, node consumes more energy since same path is used for data transfer.

The proposed routing mechanism will consider node energy for data transfer. If the node energy reduces to a certain level, an alternate path is selected for data transfer. The alternate path will improve the network life time because residual energy based data transmission decreases the death of nodes in the network.

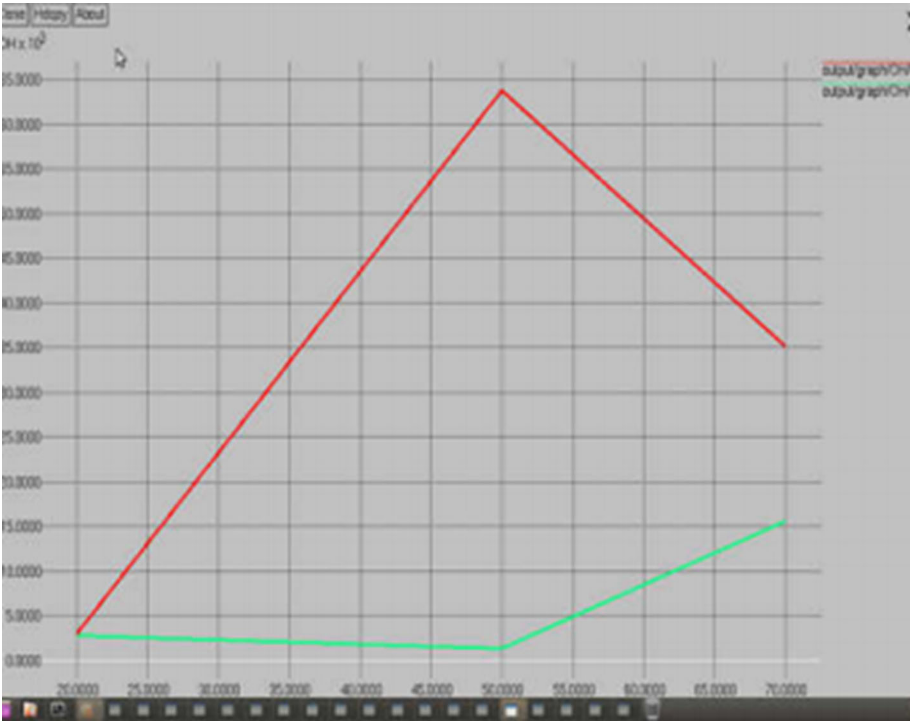

Fig. 4 Overhead comparison between proposed and conventional routing mechanism

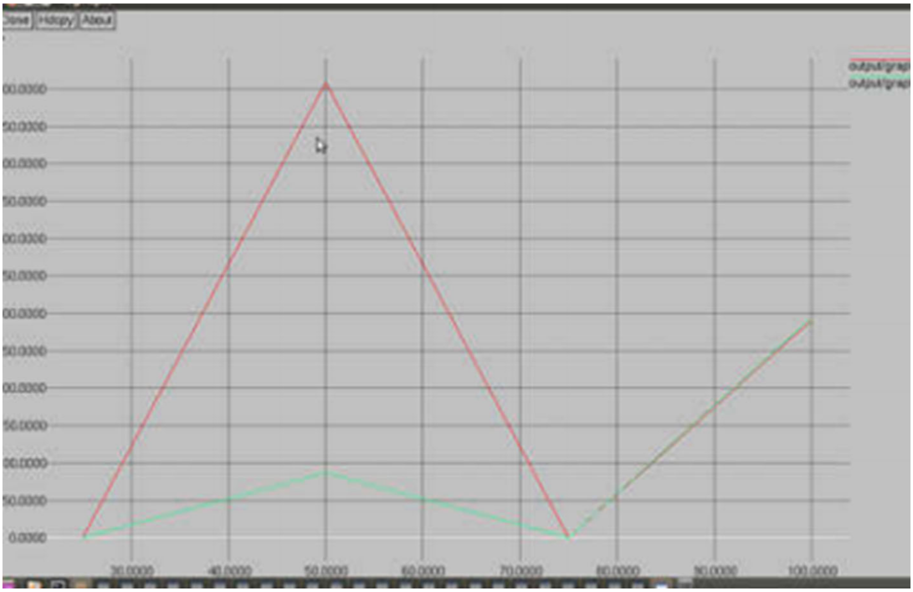

Fig. 5 Delay for residual energy based routing and conventional routing

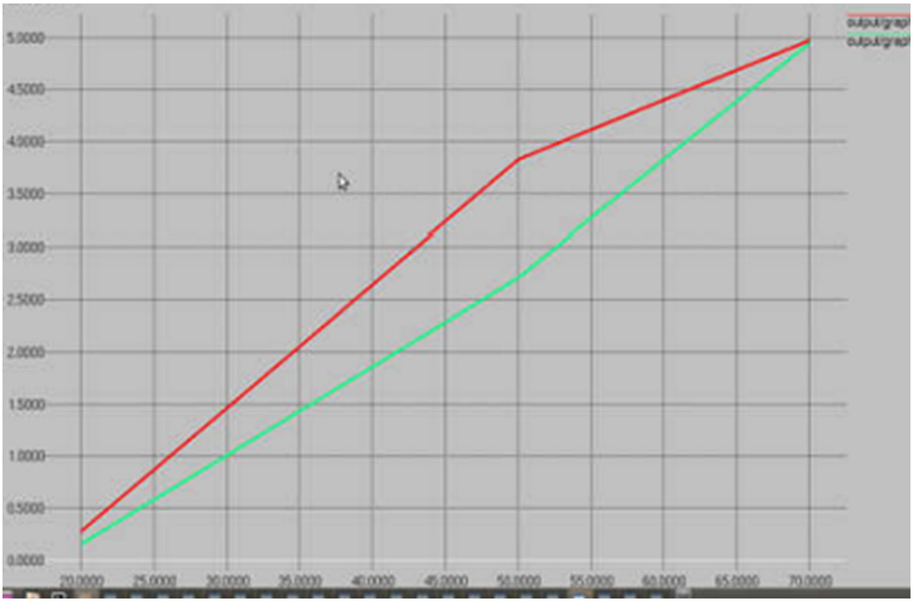

Fig. 6 Energy consumption of proposed and conventional routing mechanism

7.3 Packet Delivery Fraction (PDF)

PDF is one of the parameter which can be used for evaluating the network performances. PDF shows ratio of the number of packets received from total number of packets transmitted to the destination. For an efficient network, the value of PDF should be high indicating that minimum data loss occurred while transmitting the data to the destination. The chance of data loss during the transmission is high since the attacker in the network will try to obtain the data while transmitting through the network. So the high value of PDF for proposed mechanism shows that packet sent by the source through the intermediate nodes reaches the destination without any data loss. Figure 7 shows the improvement of packet delivery fraction by using residual energy based routing. The red line shows the PDF for conventional routing while green line shows for residual energy based routing. The graph below indicates that the proposed routing mechanism based on the residual energy and the hop count is an efficient method for data transmission because the proposed routing improves the PDF since the loss of data during the transmission is decreased. In conventional routing method the data from source to destination with minimum hop count was only considered for data transfer so that the chance of attacks in the network during the data transmission is high which causes the data loss. This problem can be minimized by using the proposed routing mechanism, if any trouble occurs to the intermediate nodes while transferring the packet to the destination it will send messages to the source to change the path for data transfer. When the source receives this messages, it will find an alternate best path which considers the node residual energy and hop count for data transmission, so that the loss of data from intermediate nodes can be avoided which improves PDF.

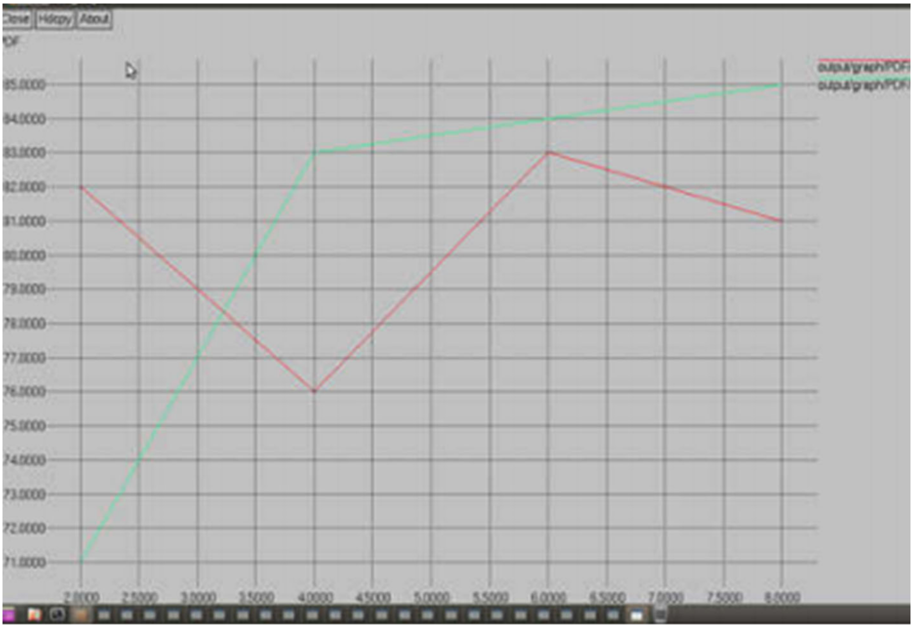

Fig. 7 PDF comparative study for both existing and proposed routing mechanism

8 Conclusion

Proposed routing mechanism uses both the residual energy and hop count for data transmission. Node having maximum residual energy and minimum hop count was considered for path selection. Residual energy based routing decreases the death of nodes in the network which improves the network life time. The communication will provide high quality of services by achieving minimum delay. Thus the problem of energy consumption in ad hoc network can be reduced by this low cost method. The work can be extended to multipath routing where the data can be transmitted to the destination through multiple paths. The link failure in the network will automatically find an alternate path for data transfer which improves the network performances.

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