A SCALABLE AND POWER-EFFICIENT SOLUTION FOR ROUTING IN MOBILE AD HOC NETWORKS (MANET)

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ABSTRACT

Mobile Ad Hoc Network (MANET) is a very dynamic and infrastructure-less ad hoc network. The actual network size depends on the application and the protocols developed for the routing for this kind of networks should be scalable. MANET is a resource limited network and therefore the developed routing algorithm for packet transmission should be power and bandwidth efficient. These kinds of dynamic networks should operate with minimal management overhead. The management functionality of the network increases with number of nodes and reduces the performance of the network. Here, in this paper, we have designed all identical nodes in the cluster except the cluster head and this criterion reduces the management burden on the network. Graph theoretic routing algorithm is used to develop route for packet transmission by using the minimum resources. In this paper, we developed routing algorithm for cluster based MANET and finds a path from source to destination using minimum cumulative degree path. Our simulation results show that this routing algorithm provide efficient routing path with the increasing number of nodes and uses multi-hop connectivity for intra-cluster to utilize minimum power for packet transmission irrespective of number of nodes in the network.

KEYWORDS

MANET, routing, mobility, Graph Theory, Scalable, Power efficient, wireless network

1. INTRODUCTION

Mobile Ad Hoc Network (MANET) [1] is often characterized as a system of dynamic nodes that communicate over wireless links. It does not use towers or base stations to perform packet transmission [2, 3]. It has all mobile nodes and they move freely in the network independent of each other. Also, each node is able to send and receive data from other nodes in the network as well as it can work as a router. Also, MANET is both power and bandwidth constrained and yet it is expected to provide multi-service provisioning with end-to-end Quality of Service (QoS) provisioning to end users. QoS in MANET is defined as the collective effect of service performance with constraints on delay, jitter, system buffer, network bandwidth, number of hops, power at each node, node mobility in MANET, and packet loss. When a source node is unable to send packet to destination node, it uses another intermediate node as relay to forward packet to the destination node. Using this multi-hop connectivity for the packet transmission, we can save power at each intermediate node [4, 5]. However, since the nodes move freely, maintaining continuous path connectivity imposes additional complexity. MANETs rely on all participating

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nodes to share the task of routing and forwarding peer traffic. Thus, it is very necessary to develop a routing algorithm which can be efficient and resource saving as well in terms of power and bandwidth usage. It can improve the overall efficiency of the network to provide quality of service (QoS) assurance for the required application. Also, the performance efficiency achived with a small set of nodes must be scalable for large set of nodes. Furthermore, in MANET, fast and unpredictable topology changes due to nodes mobility, and channel capacity vary due to environmental effects. Thus, it is more prone to errors compared with that of wired networks and reduces the overall network throughput than equivalent wired network.

This paper is organized as follows. Section II describes literature review. The basic system design is described in Section III followed by acceptable performance of graph theoretic routing algorithm in section IV. Section V concludes the paper.

2. BACKGROUND

A communication system requires packet transmission process. This packet transmission can be done after finding a path from source to destination. Thus, a routing path is required to deliver a packet from source to destination in the network. There are many routing algorithms have been developed by researchers for different kind of networks [6, 7, 8, 9, 10, 11, 12]. We had discussed many routing protocols with their advantages and limitations in our previous research [4, 5] and these limitations prohibit them to be useful for deployment in a scalable MANET. Most of these algorithms which have evolved over years for wired internet are not suitable for scalable MANET application. MANET is wireless ad hoc network which consists of mobile nodes. Also, wireless channel is more prone to error than wired channel. It can be influenced by obstacles, weather conditions and different kind of disturbance occurred in wireless channel. Reactive routing protocols use flooding technique to find the new route if an existing route breaks and thus it will direct to more packet loss in deciding the on-demand routing algorithm. It uses much network overhead in finding the new route and ad-hoc networks have very limited resources therefore it's not adequate idea to use more resources to find new route even if there is no guarantee that new selected route will be more effective than previous one. In comparison, proactive routing protocols provide higher routing efficiency in scattered traffic pattern and high mobility network. It maintains all the routes periodically thus it is very feasible to change the route at any point. It avoids finding of new route on demand. This technique does not use flooding technique and therefore it doesn't add any extra overhead to packet and saves available bandwidth usage accordingly. In our previous papers, we demonstrated a reason to develop a scalable and power efficient routing algorithm which can provides preemptive action and handles mobility by using multi-hop connectivity and send packets through less contended path. Many researchers provide their multi-hop connectivity based on shortest path and minimum power. But this shortest path is not always efficient in terms of provide efficient transmission which utilize less amount of resources and minimize the total transmission delay.

As per author's knowledge, there is no research published which can help to find a route for packet transmission over minimum contended path. Here we are presenting an idea to route packets through minimum cumulative degree path using the graph theoretic routing algorithm for cluster-based MANET where degree is calculated as number of incoming links to particular node [13, 14, 15, 16].

3. SYSTEM MODEL

We have considered a cluster based MANET architecture and it is explained in detail in our previous research paper [4] as well as it is shown in Fig.1 as below. The proposed scheme develops a route for packet transmission from the source node to a destination node based on the available degree and congestion at each node. This newly developed routing algorithm reduces the scheduling time at each node by selecting the least congested node first in routing path; consequently this reduces the overall delay and accomplishes the targeted QoS for the application. In addition, it is proactive routing and it saves bandwidth and power at each intermediate node consequently to increase efficiency of the MANET. In this section, we will show that our designed algorithm is scalable and it is power efficient. Here we used multi-hop connectivity for the packet transmission and our simulation results show that the multi-hop connectivity is more power efficient than the direct transmission. It also proves that the developed routing algorithm is scalable. The newly developed route will always be efficient in terms of transmission delay and network throughput despite of the increasing nodes in the network.

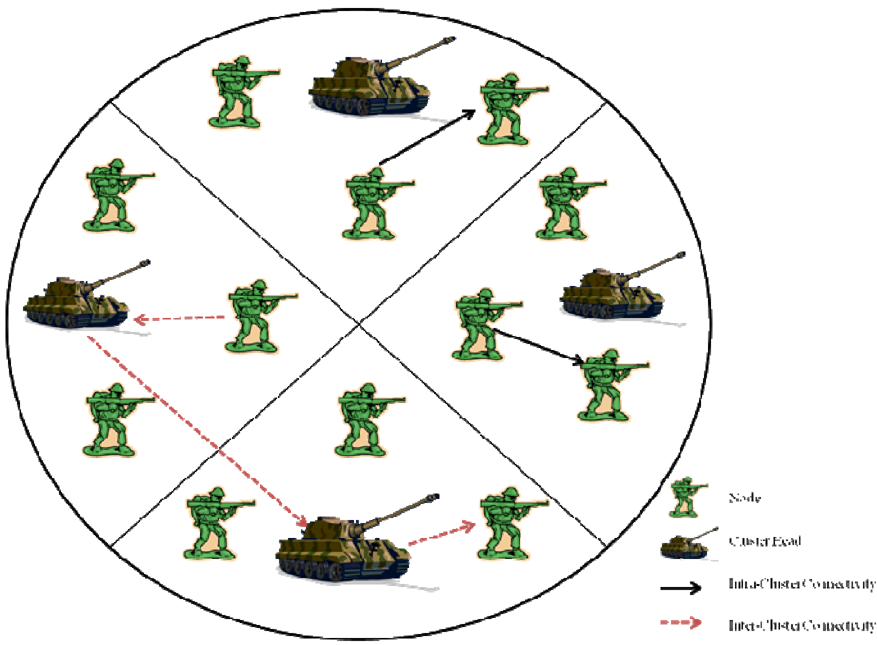

Figure 1. MANET Architecture

3.1. Power Efficiency

In packet transmission from a source to the destination, we should consider the processing power as well as the transmission power for the packet. Processing power is the power which is used to calculate the route as well as to generate a new packet to send. The main aim of power control is to reduce the total power consumption at each node and increase the network lifetime by increasing the residual power of battery. However we can achieve multiple benefits by controlling the transmission power in an ad hoc network and alleviate the impact of interference by using less amount of power at each node using multi-hop connectivity to satisfy QoS requirement for the appropriate application. Optimal power consumption in ad hoc network can be achieved by following techniques.

Power required to transmit a packet from source to destination is calculated based on the distance between them. For a transmission from source node k to destination node j at data rate R, separated by a distance d_{kj}, the transmitter power at k is modeled by eq. 1 as shown below.

$$P=R*d_{kj}^{\alpha} \tag{1}$$

Where α is the channel loss exponent (typically between 2 and 4, depending on the channel medium) [17]. Throughout this research, we assume α = 3. We are working in wireless medium and channel conditions are not fixed in wireless medium. Sometimes there may some interference available in channel thus at that time our = 4 and in case of absence of interference α = 2. There is always zero probability of having interference, Therefore, for the better safe side, we considered α = 3. It is obvious that the direct communication requires higher transmission power from source node than Multihop communication.

$$(d_1 + d_2 + d_3 + ... + d_n)^{\alpha} >> d_1^{\alpha} + d_2^{\alpha} + d_3^{\alpha} + ... + d_n^{\alpha} \tag{2}$$

From equation 2, we can say that the long range transmission consume more power in transmission than total sum of several shorter range transmission [18, 19]. Therefore, each node can save power and increase the network lifetime.

3.2. Scalability

A network size can be very depending on the application. Ad hoc network is mainly used in Battle field theatre applications and emergency disaster management. In this kind of applications, network size can't be predicted in advance and therefore, all solutions related to mobile ad hoc network should be scalable as well as power efficient. Routing in mobile ad hoc network has been an interesting topic for research since long time. Also, graph theory has been applied to lot of static problems. Here, we developed a graph theoretic based routing algorithm for dynamic ad hoc network. Routing algorithm should be designed in such a way that it doesn't affect the network performance even if the number of nodes increases as per the desired application. In our previous research [5], we have designed an algorithm to determine the number of intermediate nodes based on the location of destination node and source node. Using the method of power circle, we can find the total number of intermediate nodes which can relay the information from the source node to the destination node. We also showed that the algorithm is capable of handling the mobility of the nodes. Our routing scheme is applicable to the inter-cluster as well as intra-cluster connectivity.

4. Simulation Results

We had simulated the MANET architecture on MATLAB software. In order to perform this simulation, we developed a MANET where all nodes are randomly distributed and its area 200 x 200 meters. We have also allowed each node to move randomly and independent. Figure 2 demonstrate the random distribution of 50 nodes in the whole network. To prove the scalability of the network, we vary network size till 200 nodes. We have selected a random source and a destination node which can communicate by selecting a path from our developed routing algorithm using minimum cumulative degree.

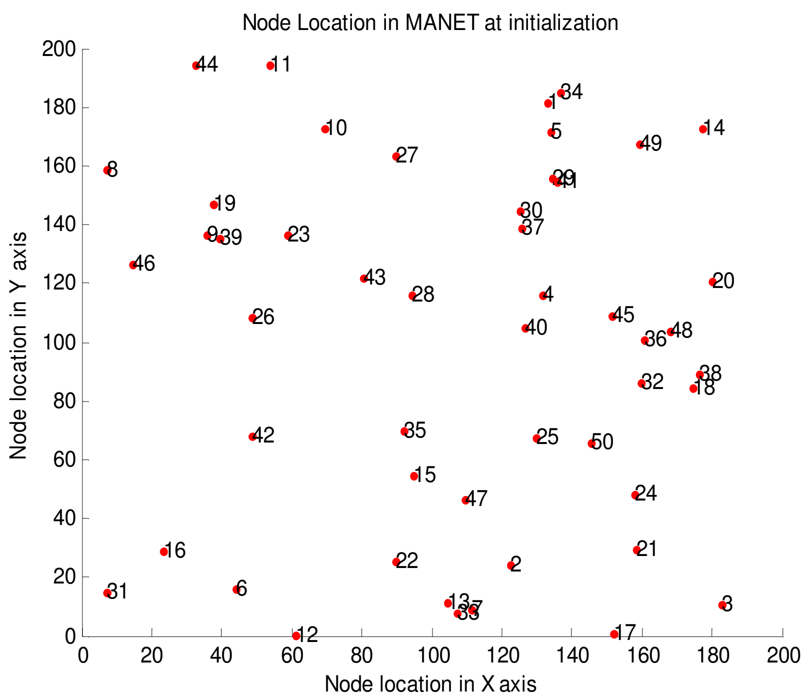

Figure 2. Random distribution of nodes in the network

4.1. Power Efficiency

MANET is combination of mobile nodes which has limited power. Thus, in order to prove the power efficiency of the graph theoretic routing algorithm, we have simulated different number of source-destination pairs and measure the power of each transmission. Figure 3 shows that the multi-hop connectivity gives better power utilization at each node. Using multi-hop connectivity we can save power at each intermediate node and increase the network life consequently. For the case shown in Fig.4, source node sends packets to destination node using one intermediate node and the power calculation for this case is calculated using the equation. 1 as indicated in table 1. Also, for the same source and destination pair, the source node sends packet to the destination node using two intermediate nodes as shown in Fig. 5 and its power is calculated in table 2. By comparing table 1 and 2, we can conclude that using multi-hop connectivity, each node has to utilize less amount of power rather than direct transmission. In addition, in this case, the total power required to send packet from the source node to the destination node is lesser when source node utilize two intermediate nodes.

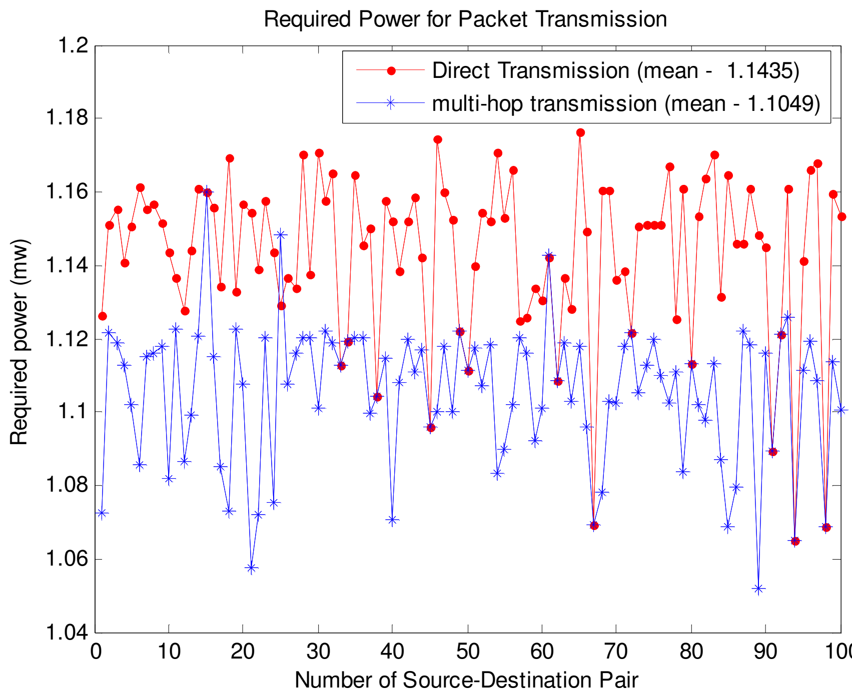

Figure 3. Direct Transmission Vs. Multi-hop Transmission

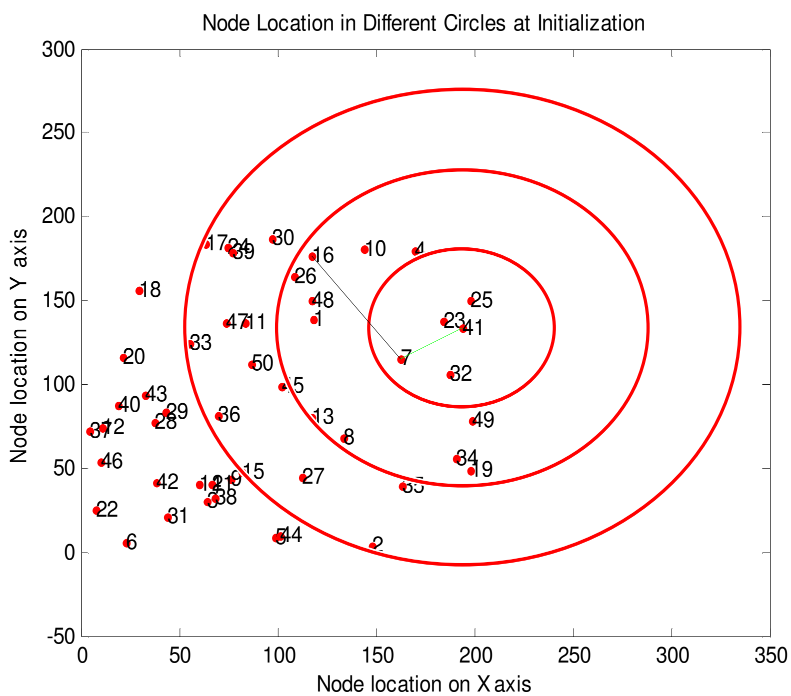

Figure 4. Source to Destination Connectivity using Single Intermediate Hop

Table 1. Power Calculation for Case shown in Fig. 4

	From Node 41 to node 7	**From Node 7 to node 16**	**Total**
Required Transmission power (mw)	0.497	4.518	5.0162

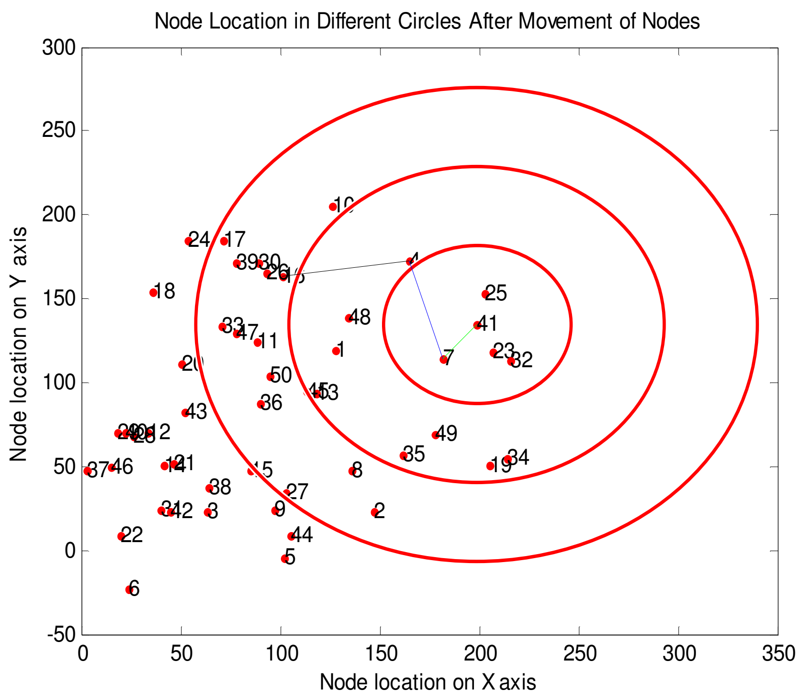

Figure 5. Source to Destination Connectivity using Two Intermediate Nodes

Table 2.Power Calculation for Case shown in Fig. 5

	From Node 41 to node 7	**From Node 7 to node 4**	**From node 4 to node 16**	**Total**
Required Transmission power (mw)	0.186	2.164	2.627	4.978

We also measure the end-to-end power for 50 and 100 source destination pairs and it is illustrated in Fig. 6 and Fig. 7 respectively. These simulation results shows that the overall transmission power for different source-destination pair for two separate algorithms. It proves that the power required by graph theoretic routing algorithm is lesser than the shortest path algorithm. We also increase number of nodes in the network to verify the power efficiency of the designed algorithm and proved that the graph theoretic routing algorithm performs better than the shortest degree path algorithm. It is shown in Fig. 8.

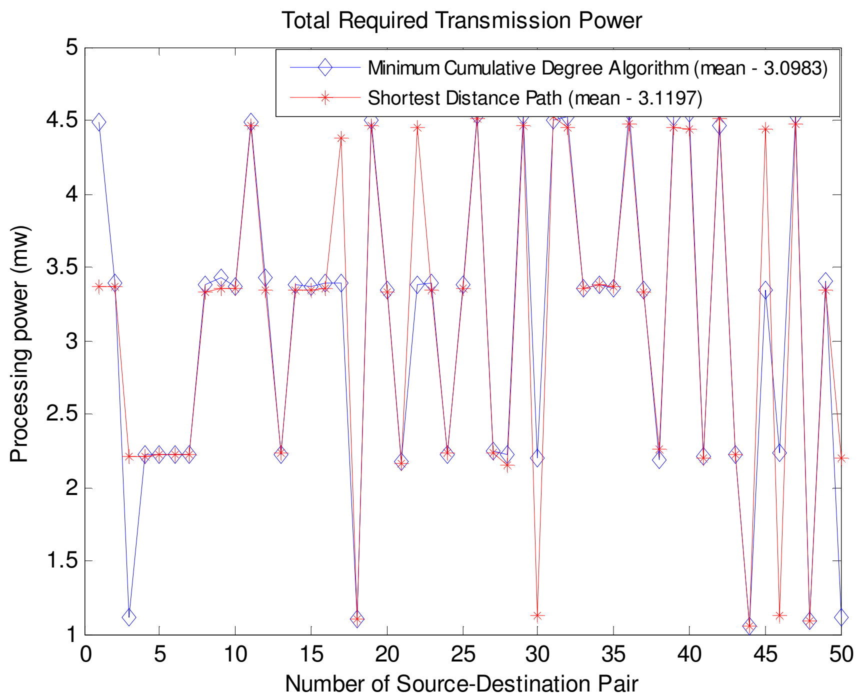

Figure 6. Total Required power for each source-destination pair

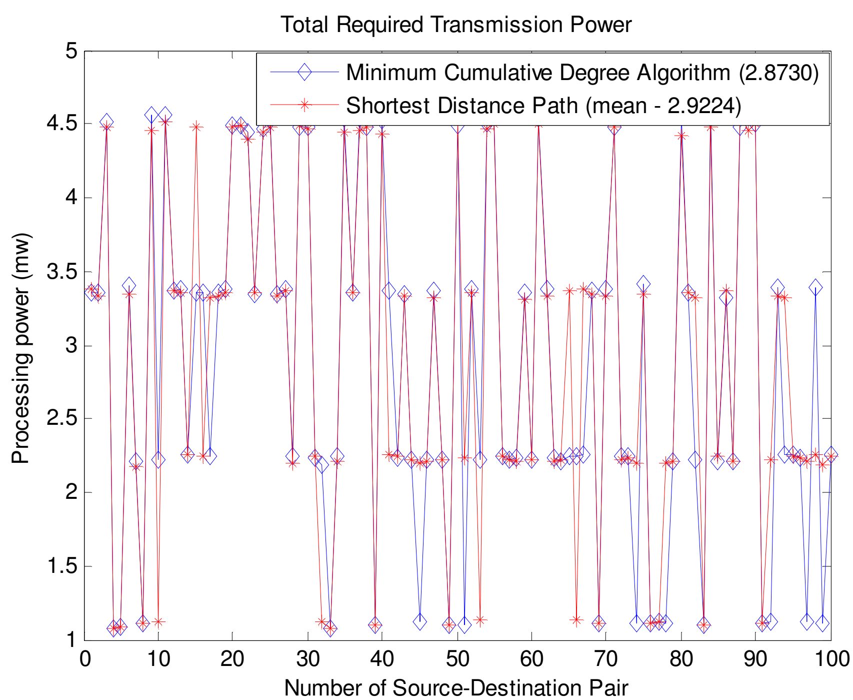

Figure 7. Total required power for each source-destination pair

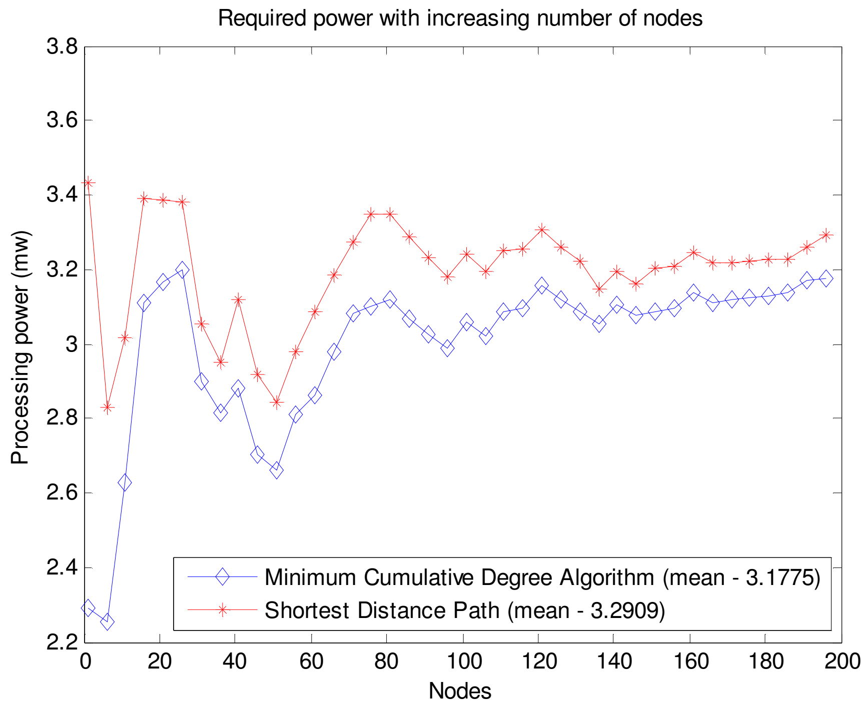

Figure 8. Total required power for different size of networks

4.2. Scalability

To demonstrate the scalability for the MANET using minimum degree based routing algorithm, we have only considered intra-cluster connectivity in this research paper. Here we have simulated a MANET for 100 different source-destination pairs and each time source-destination pairs selected randomly. For the first case as shown in Fig. 9 we have simulated 50 pairs and we can see that minimum degree based routing path has less number of degree with compared to shortest distance path. Shortest distance path routing algorithm derives a path without knowledge of congestion at each node based on its degree and graph theoretic routing develops route based on node's available congestion. Thus, degree is directly proportional to delay of packet transmission and therefore, minimum degree algorithm provides lesser delay in packet transmission. In the second case, we have increased our simulation for 100 different random source-destination node pairs and we got the same result as we got in Fig. 10. We also extended our research to prove scalability of the algorithm, we varies network size from initial condition to 200 nodes. And each time we have some source-destination pairs. Fig. 11 shows the mean value of total cumulative degree in each case. It also shows that as number of nodes increases, our newly developed algorithm gives better performance and reduces overall delay and increase throughput of the network.

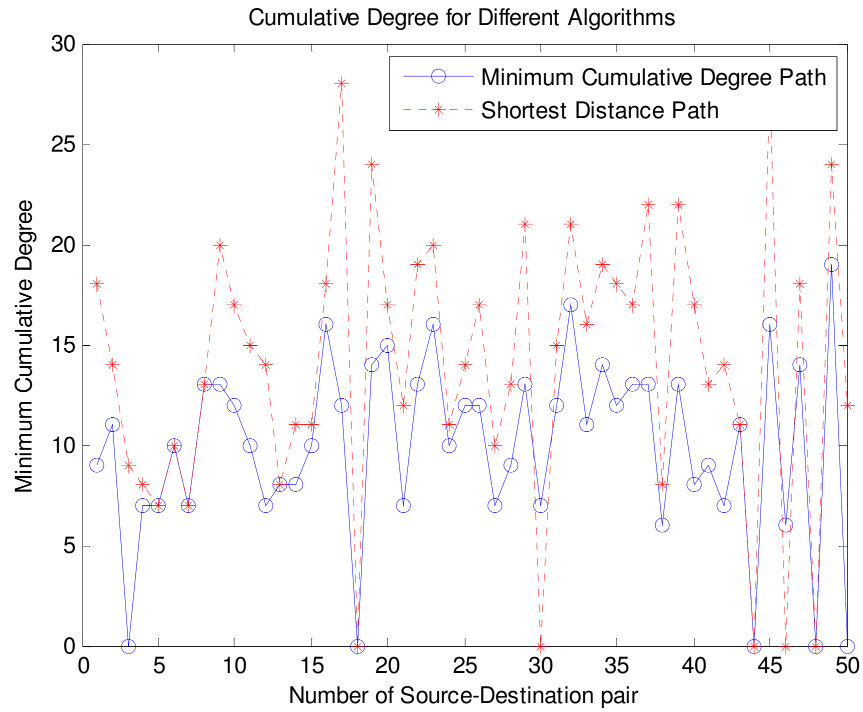

Figure 9. Cumulative degree for each source-destination pair

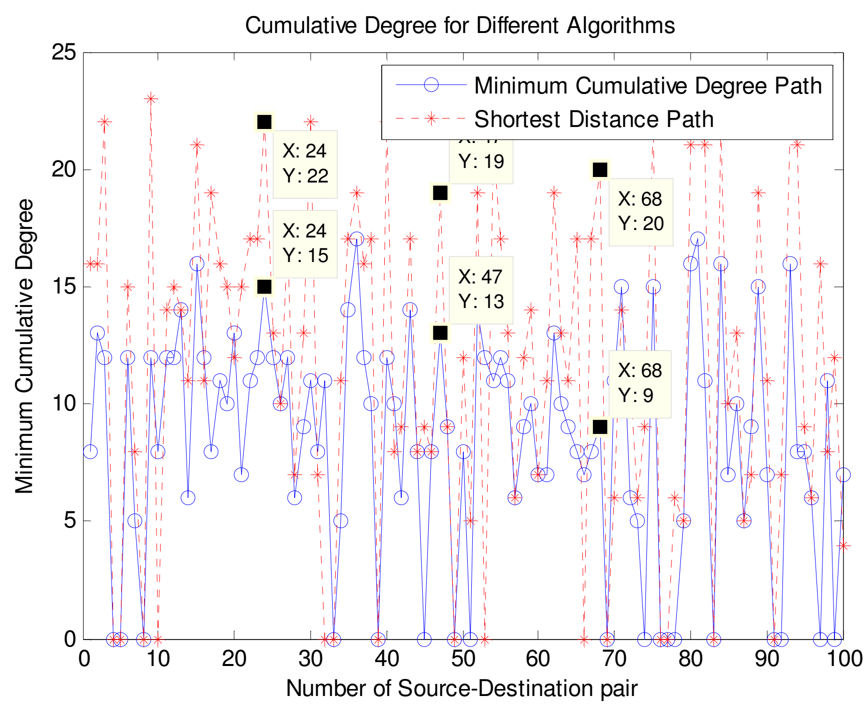

Figure 10. Cumulative Degree for each source-destination pair

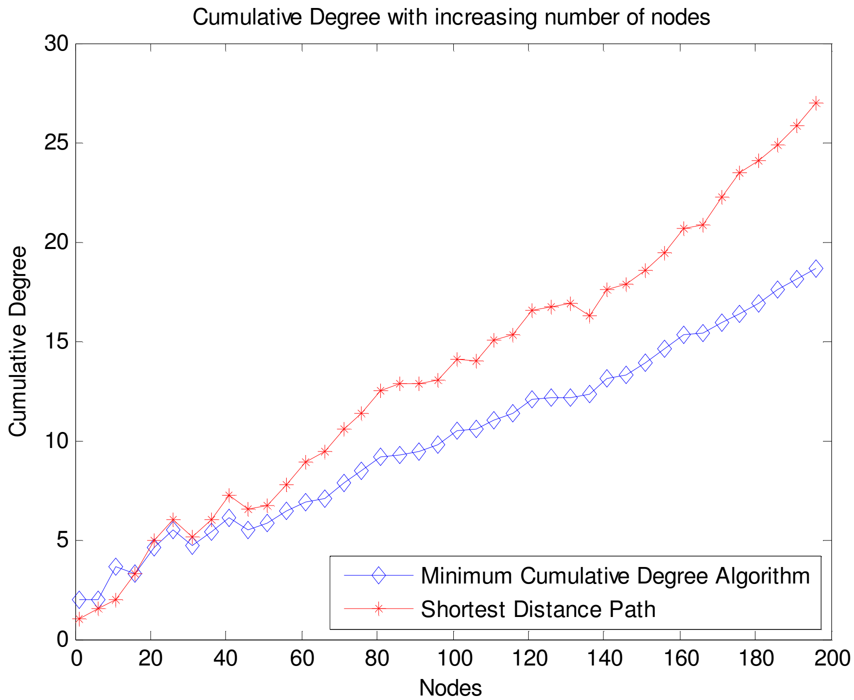

Figure 11. Cumulative Degree for different size of networks

5. Conclusion

MANET is a dynamic network and therefore, it is a critical to route packet in this kind of network. Here, we developed a graph theoretic routing algorithm for inter-cluster as well as intra-cluster network. We designed all identical nodes except cluster head and thus we reduced management overhead in order to provide highly efficient routing for the packets to deliver at destination. By simplifying and using the minimum cumulative degree path as a preferred route to destination, we can minimize the overall delay and increase the throughput as well as network life by using multi-hop connectivity to save power at each intermediate node. In addition, our simulation results proves that the average processing power required at nodes with buffer is higher as compared to node without buffer in ad hoc network. Also, this routing algorithm is scalable and provides preemptive action which reduces the overall packet loss and able to provide efficient packet transmission.

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