Minimum Energy Dynamic Source Routing Protocol for Mobile Ad Hoc Networks

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Abstract— **Many energy conserving routing protocols have been proposed for Mobile Ad Hoc Network (MANET). Those protocols show that energy consumption in MANET can be reduced by adjusting the transmit power to a minimum level. To determine the minimum transmit power is a challenging issue. A reduced transmit power can cause network partitioning. In order to determine the correct transmit power, mobile node usually uses additional control messages like 'Hello' messages to collect information of its neighbors. That causes a huge overhead which is not desirable. In this paper, we propose a Minimum Energy Dynamic Source Routing (MEDSR) protocol for MANET that ensures connectivity of the network. The Dynamic Source Routing (DSR) protocol has been modified in order to implement MEDSR protocol. Existing control messages of DSR protocol have been modified and used in MEDSR protocol. That is why no additional control message is required. We present an analytical model to show that a considerable portion of energy can be saved by using MEDSR protocol. The MEDSR protocol has been implemented and tested via a Network Simulator (NS-2). The simulation results show that the MEDSR protocol decreases per packet energy consumption. Hence it can deliver more useful data packets compared to DSR protocol.**

Index Terms— **Wireless Network, minimum energy, transmit power, cross layer, connectivity**

I. Introduction

IN the recent years, there has been growing interest in Mobile Ad Hoc Network (MANET) as a means of providing instant networking to a group of mobile nodes which may not be within the transmission range of each other. MANET is self-organizing, self-configuring and self-maintaining. In MANET, mobile nodes communicate with each other in a multi-hop fashion. That is why the availability of each mobile node is equally important for the proper operation of the whole network. The failure of a single mobile node can greatly affect the overall performance of the network. Since each mobile node has a very limited battery life, one of the major reasons of node failure is the battery exhaustion. Many routing protocols have been proposed for MANET in order to achieve energy conservation. Those protocols use different approaches in order to save energy in MANET, which can be broadly classified as - (1) Transmit Power Control approach [1], [2], [3], [4], [5], [6], (2) Load Distribution approach [7], [8], and (3) Sleep-power Down approach [9], [10]. In transmit power control approach, the transmit power of mobile node is controlled in order to maintain the connected topology of the network. The main objective is to find the best route that minimizes the total energy consumption while transmitting packet between a source and a destination. In [1], the optimal routing path is selected based on the minimum sum of link cost between a source-destination pair. The link cost is derived based on the initial and the residual battery energy of a mobile node. In [2], two different matrices of network nodes are optimized - minimizing power consumption and maximizing the minimal residual energy. The optimal path is selected based on Dijkstra's algorithm using link cost information. Routing algorithm based on global information of the network such as data-generation rate or power-level information of all nodes are used to select a path in [3]. Minimum energy routing protocol has been proposed in [4]. The minimum energy protocol is based on the fact that a mobile node should transmit packet at a power level which should be just enough to reach the next hop. A margin of 3 dB was added with the minimum power in order to cope with the channel randomness. The source route contains information about the minimum transmit power between the links. If each data packet carries power information in addition to source routing information, the packet size will increase. Those large packet needs longer time for transmission. Hence occupy more bandwidth. That is why including link by link power information in each data packet may not be a good choice in source routing protocol like Dynamic Source Routing (DSR) [12] protocol. Retransmission-Energy aware routing (RAR) protocol is proposed in [5]. Link error rate has been taken into account in order to determine optimal transmit power. Smallest Common Power (COMPOW) protocol [6] selects the smallest power level which is just enough to maintain connectivity of the entire network. Each node selects different power levels and build routing tables for each power level. By exchanging that routing information among themselves, mobile nodes decide about the minimal power level that ensures connectivity of the entire network. But that kind of routing information exchange can cause excessive routing overhead in the network, which can affect the performance of the network. The main objective of the load distribution approach protocol is to distribute the traffic load among the network nodes. A quantitative analysis shows in [17] that the nodes located near the center of the network carry more traffic compared to other nodes located near the perimeter of the network. The load distribute approach protocols reduce the chance of using over utilized nodes while selection a path. In localized-energy aware routing (LEAR) [7] protocol, a mobile node decides whether to forward or not to forward

traffic for other depending upon the residual battery energy. If the residual battery energy is greater than a threshold, a mobile node forward the traffic for other. The DSR protocol has been modified in order to implement LEAR protocol. Conditional Max-Min Battery Capacity Routing (CMMBR) [8] protocol is similar to that of LEAR protocol. If all nodes in some possible route between a source-destination pair have larger remaining battery energy than the threshold, the min-power routes among the discovered routes are selected. If all possible routes have nodes with lower battery energy than the threshold, the max-min route is selected. In sleep-power down approaches, the energy is saved by turning the mobile node into sleep mode or power down mode. Most of the radio hardware can operate in different power states. The routing protocols which falls in this category are focused on the decision when to turn off the power or to go into the sleep mode. In SPAN protocol [9], coordinator eligibility rules are employed by the mobile nodes in order to determine the 'master'. The rule is that if two neighboring nodes can not reach each other directly or via one or two masters, it should become master. Once becoming a master, a master node periodically checks if it should withdraw as a master. Non-master also periodically determines if it should become master. That kind of switching between master and ordinary node ensures that the network traffic is distributed among the nodes. The 'Hello' message is used in order to collect information about the neighbors in order to decide which node will be master or which node will be ordinary node. That kind of 'Hello' message incurs additional control overhead in the network. In Geographic Adaptive Fidelity (GAF) protocol [10], each node uses location information based on Global Positioning System (GPS) to associate itself with a 'grid' so that the entire network area is divided into square grids, and the node which has the highest residual battery power in each grid becomes master node. Other nodes in the grid are put to sleep. To provide each mobile node with GPS system may not be suitable solution in terms of software or hardware complexity specially when mobile nodes have very limited memory resources and limited processing power.

Above approaches suggest that energy aware routing protocols save energy. But those protocols incurs additional control overhead, which can consume unnecessary bandwidth of the network. Additional hardware or software is required in some protocols, which may not be feasible for the mobile nodes. Because mobile nodes usually have low processing power and limited hardware resources. In this paper, we propose a minimum-energy routing protocol called Minimum Energy Dynamic Source Routing (MEDSR) protocol. Our approach is to avoid additional control message. Existing control packets of DSR protocol have been used in order to implement the MEDSR protocol. The MEDSR protocol works in two phases - route discovery and link by link power adjustment. Two power levels have been used during the route discovery phase of the protocol. At first, a source node initiates the route discovery to find a route to its destination by broadcasting a request packet at low power level. If the source node discovers a path using that power level, it set up the connection using that power level. If a source node can not discover a route to its destination using that low power level after initiating route discovery for a certain number of times, it assumes that the destination is not reachable at that power level. Then it increases the power level to a higher value and initiates the route discovery again at that power level. We use cross layer concept in MEDSR protocol. The network layer control packet like route request packet is used to determine the physical layer transmission radius. Once route is discovered by using any of those two power levels, link by link transmit power is adjusted to save more energy. That kind of link by link power is adjusted using the network layer route reply packet. The DSR protocol has been modified in order to implement the MEDSR protocol. It is shown in later section that even if a route is discovered at high power level, link by link power adjustment can saves a considerable portion of energy. In the next section, we will show some analytical model and our motivation of this work. In section 3, we will explain the DSR protocol in brief. In section 4, we will present the MEDSR protocol in details. In section 5, we will show some simulation results and section 6 will conclude our works.

II. Energy Model

In this section, we present the energy model used for our analysis. The energy consumption in ad hoc network has been investigated in [11]. Some experimental results, which have been presented very recently in [15] show that the energy consumption in ad hoc network is different from that given in [11]. But the authors have not presented any mathematical expression about the energy consumption. The results are solely based on experiments conducted in the laboratory. That is why we will also use the model developed in [11]. Similar model has been used in [4]. That model shows that the energy expended in sending a data-packet of size D bytes at a transmit power of P_t can expressed as

$$E(D,P_t) = K_1 P_t D + K_2 \quad (1)$$

,where the typical values for K_1 and K_2 in two frame exchange 802.11 MAC environment at full power (280 mW) and a 2 Mbps bit rate are $4\mu s/byte$ and $42\mu Joules$ respectively. In order to simplify our analysis, we focus only on the energy consumption related to data packet. Since the MAC layer related packets (CTS,RTS,ACK) and Network layer related packets (route request and route reply) are very smaller in size compared with the size of a data packet, we ignore the energy consumptions related to MAC layer and Network layer packets in our model. Now, for a given threshold power P_{th}, the minimum transmit power P_{min} required for successful reception of packet can be expressed as as

$$P_{min}(d) = \frac{P_{th} d^n}{K} \quad (2)$$

,where d is the distance between the two nodes, n is the path loss exponent and K is a constant. Typically n takes value of 2-4. In our analysis we use 4.0 which represents path loss

exponent for two-ray model [13]. The typical value of P_{th} in LAN 802.11 is 3.652^{-10} mW. Substituting the value of P_{min} into Equation 1, we get the minimum energy consumption as

$$E_{min} = K_3\,(D)\,d^4 + K_2 \quad (3)$$

,where K_3 has the value of $2.8 \times 10^{-10} \mu J/(byte - m^4)$. We can conclude from Equation 3, that the minimum energy consumption depends on the distance between two nodes. On the other hand, the transmit power is fixed at 0.281838 mW (250 meter radius) in DSR protocol. The energy consumption in DSR protocol can be expressed as

$$E_{max} = K_4 D + K_2 \quad (4)$$

,where K_4 has the value of $1.162 \mu J/byte$. The detail derivation of Equation 4 can be found in [4]. Thus the energy savings that can be obtained by using the minimum transmit power instead of fixed maximum power is given by

$$S(D,d) = E_{max} - E_{min} \quad (5)$$

We now extend our idea of minimum energy saving formulation between two nodes scenario to a uniform random network scenario. In that scenario, the locations of the mobile nodes are determined according to uniform random variables. To compute the probability of link distances between any source-destination pair in that kind of random network, we rely on the results presented in [14]. In [14], it is shown that the distribution of the distances between sources and destinations can be expressed in terms of $x = \frac{b}{a}$, where a and b are the length and the width of the network. The cumulative distribution function (cdf) of the link distances in terms of x is given as

$$P(d \le bx) = \begin{cases} 0 & x \le 0 \\ x^2(\frac{1}{2X^2} - \frac{8}{3x} + \pi) & 0 \le x \le 1 \\ \frac{4}{3}\sqrt{x^2-1}(2x^2+1) & \\ -(\frac{1}{2x^2} + 2x^2 - \frac{1}{3}) & \\ +2x^2[sin^{-1}(\frac{1}{x}) - & \\ cos^{-1}(\frac{1}{x})] & 1 \le x \le \sqrt{2} \\ 1 & x \ge \sqrt{2} \end{cases}$$

(6)

Taking the derivative of the cdf function, we get the probability distribution function $p(x)$. Hence the expected distance of the link can be expressed as $d = \int_{x=0}^{x=\sqrt{2}} xp(x)dx$. A typical variation of the expected link distances with the varying network size from 400m by 400m to 1000m by 1000m is shown in Figure 1.

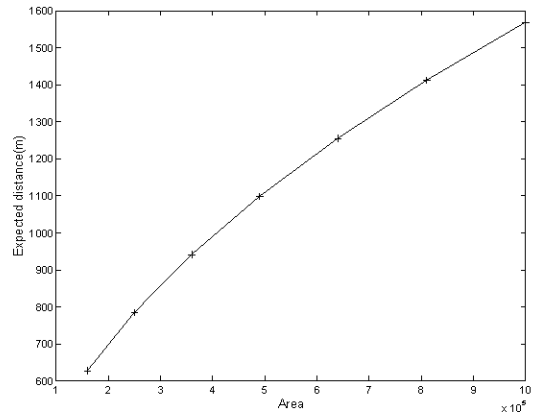

Fig. 1. Expected Link Distance between two nodes under varying network area

Let us assume that for a particular network area, the expected distance between a source and a destination node is given by d. In DSR protocol, the transmission radius is fixed and assume that transmission radius is given by R. So the number of hop that a packet travels from its source to its destination can be expressed as $H = \frac{d}{R}$. The total energy consumed while transmitting a packet from the source to the destination can be expressed as

$$E_1 = E_{max} \times H \quad (7)$$

,where E_{max} is given by 4. On the other hand, if we select smaller transmission radius r, where $r \le R$, the packet will travel $h = \frac{d}{r}$ hops from the source to the destination. If the minimum transmit power is used, the energy expended for transmitting data packet from the source to the destination can be expressed as-

$$E_2 = \sum_{i=1}^{h} E_{min,i} \quad (8)$$

,where $E_{min,i}$ is the energy consumption while transmitting packet in the ith hop and which given by 3. Based on the model developed in this section, we show an example where 80 mobile nodes have been placed randomly over an area of 700m by 700m. For that network size, the expected distance between an arbitrary source and destination is around 1100 meter which can be found from Figure 1. For DSR protocol, the number of hops is equal to 5, which is given by $\lceil \frac{1100}{250} \rceil$. If we now choose a transmission radius of $r \le R$, the number of hops the packet will travel becomes equal to or greater than the number of hops in DSR protocol. If minimum energy routing scheme is used, The total energy consumption can be found using using 8. The energy saving that can be achieved using minimum energy routing compared to DSR protocol is shown in Figure 2. From that figure, it can concluded that if a small transmission range is used, the packet will travel a large number of hops, but still

it can save energy. But a very large number of hops is not a feasible solution. Large number of hops incurs large delay, network partitioning and also excessive overhead. In order to overcome those limitations, we choose two power levels- a low power level which corresponds a transmission radius of 125 meter and a high power level which corresponds to a transmission range of 250 meter. Those ranges will be used in the route discovery phase of the MEDSR protocol. If a source can discover a route with a small power level, the number of hop will be twice as much as that of DSR protocol. But still the MEDSR protocol will save energy. If a source can not find the route, it will use higher power level. In that case, the number of hops will be equal to that of DSR protocol. Since in both cases, link by link transmit power is adjusted to a minimum level, the MEDSR protocol will save energy whether the hop number is larger than or equal to DSR protocol. Since we modify the DSR protocol in order to implement MEDSR protocol. In the next section, we will give a brief explanation of DSR protocol.

III. Dynamic Source Routing Protocol

The DSR protocol is based on source routing. The originator of each packet determines an ordered list of nodes through which the packet will travel to reach the destination. The DSR protocol is composed of two main mechanisms-route discovery and route maintenance.

Route discovery is the mechanism by which a source node discovers a route to a destination. When a source node has some packet to send to a destination, it will search its cache to find a route for that destination. If it can not find route in the cache, it will initiate a route discovery by sending a route request packet as a local broadcast packet,which is received by all nodes currently within wireless transmission range of this node. Each route request contains the source and the destination addresses and it also contains a unique request id. Each request packet also records a list of the nodes through which it has been forwarded. When a node receives that route request packet, it checks the unique request id to determine whether it has already processed that request or not. If it has already processed that request packet, it drops that duplicate request packet. Otherwise it checks whether it is the destination of that route request or not. If it is not the destination,it appends its own address in the route request packet and re-broadcasts that route request packet to its neighbor with the same request id. This process goes on until the route request packet reaches the destination node. On the other hand, if it is the destination, it sends a route reply packet to the source node after copying the accumulated route from the route request packet in the route reply packet. When the source node receives the route reply packet, it records the new source route in its cache and starts sending packet using that new route that it has just discovered.

Route maintenance is the mechanism by which a node is able to detect any changes in the network topology. In DSR protocol, each node which is transmitting the packet is responsible for confirming that the packet can flow over the link from that node to the next hop. An acknowledgment

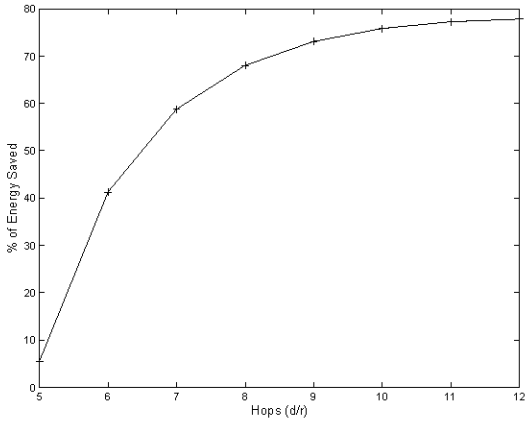

Fig. 2. Energy Saving in random network

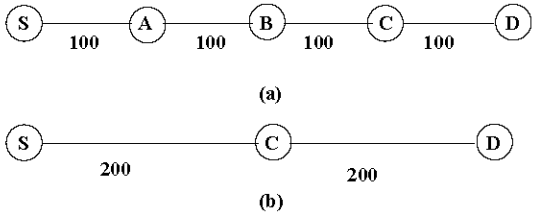

Fig. 3. Route discovery in (a) low power and (b) high power

provides confirmation that the link is capable of carrying data to the next hop. This type of acknowledgment is provided by the existing MAC layer protocol, (IEEE 802.11). After sending the packet to the next hop, the transmitting node waits for an acknowledgment. If it does not receive an acknowledgment, the transmitting node treats the link to the next hop is 'broken'. It marks all the routes in the route cache that uses that link as 'invalid'. It will return a route error to each node that has sent a packet over that broken link so that all those nodes can update their own route caches as well. After receiving the broken route information from the route error message, the source node tries to find another route from its route cache. If it cannot find any other alternative route available in the cache, it will initiate another route discovery to find another route for that destination.

We modify the basic route discovery mechanism of DSR protocol in order to make it energy aware. We call the modified protocol as Minimum Energy Dynamic Source Routing (MEDSR) which is explained in the following section.

IV. MEDSR protocol

The MEDSR protocol consists of two basic mechanisms - route discovery and the link power adjustment. A source node uses route request packet to discover a destination node. The route reply packet is used to adjust the transmit power level between two nodes.

Unlike the route discovery mechanism in DSR protocol, MEDSR protocol uses two power levels in the route discovery phase. The basic route discovery mechanisms using low power level and high power level are shown in Figure $3(a)$ and $3(b)$ respectively.

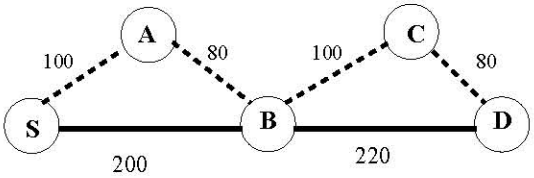

Fig. 4. Network Topology for example

A. Low Power Route Discovery

The route discovery using low power level is depicted in Figure 3(a). In that figure, when the source node S has some packet to send to a destination node D and if it can not find a route in its route cache, it initiates a route discovery process by broadcasting a request packet at low power level. The route request packet structure of DSR protocol has been modified to carry information of power level. Since the transmission range at low power level is 125 meter, the route request packet sent by node S reaches the next hop A. Node A checks the destination address of the route request packet. Since the destination address does not matches the address of node A, node A adds it own address in the request packet and re-broadcasts that request packet to its neighbor B at that same low power level. This process goes on until the route request packet reaches the destination node D. After receiving the route request packet, the destination node D replies back to source by copying the source route from the request packet into the route reply packet. The structure of route reply packet of DSR protocol is also modified in order to carry power level information. While sending route reply to the next hop C, the destination node D copies the power level information from the route request packet into the route reply packet and sends the reply packet to the next hop at that low power level. When the next hop C receives the route reply packet at power level P_{recv}, it reads the power level information in the reply packet, which is actually the transmit power P_{tx} of the destination node D. The node C can estimate the required minimum transmit power which is just enough to reach the destination node D by using-

$$P_{min} = P_{tx} - P_{recv} + P_{th} \tag{9}$$

,where all the values are in dbW. P_{th} is the required threshold receive power for successful reception of the packet. The typical value of P_{th} in LAN 802.11 is 3.652×10^{-10} Watt. To overcome the problem of unstable links due to channel fluctuations, a margin P_{margin} in dBW is included in Equation 9. Hence Equation 9 becomes

$$P_{min} = P_{tx} - P_{recv} + P_{threshold} + P_{margin} \tag{10}$$

In our experiment, we set a margin of 3.0 dB. A similar margin is also used in [4]. Node C then record the recalculated transmit power in a table called power table. In MEDSR protocol, each node maintains a power table in addition to other tables (such as request table, routing table etc.) of DSR protocol. Each entry in the power table has two values-next hop node's ID and the minimum transmit power for that next hop which is determined by Equation 10. As for example, the intermediate node C will store the ID of the destination node D and the minimum transmit power to reach that node in the power table. Node C then forward that reply to its next hop which is node B. While forwarding, the node C also used low power level (125 meter range). After receiving that route reply, node B also record the ID of node C and the recalculated minimum transmit power to reach node C in the power table. This process goes on until the route reply packet reaches the source node S. The source node now records the route just discovered in the route cache and starts sending data packet using the route it has just discovered. By this time each node including source node knows the minimum transmit power level to reach the next hop. The source checks the next hop id (ID of node A) from the source route stored in the data packet and it then retrieves the required power level for that node from its power table and transmits packet at that power so that it can reach node A. Intermediate nodes B and C also transmit packet in the similar way based on the next hop id and the power table record. Since the distances between the two nodes is 100 meter for the scenario of Figure 3(a), the source could discover the route using the route at low power level. But there are cases when a source node can not discover a route using low power level which is depicted in Figure 3(b).

B. High Power Route Discovery

In the Figure 3(b), the distances between the nodes are 200 meter. In this case, the source node can not reach the next neighbor C with low power level. In order to ensure the reachability of the next hop, the source node S will increase it power level to higher level after a certain number of unsuccessful route discovery attempts. At first the source node S will try to discover the route to its destination D using low power level. Since the distance between the source and the next hop C is 200m, the route request broadcasted by source node will not reach the next hop. After a certain number of unsuccessful attempts, the source node will increase the power level to higher level. We set the number unsuccessful attempts to 3. That means after broadcasting 3 route request packets, the source S should use high power level instead of low power level. We set that number based on the basic route discovery mechanism of DSR protocol. In DSR protocol, a 'ring zero search' method is used in the route discovery mechanism. In that method, the source node sets the maximum number of hop to 1 in the route request packet so that the route request should not propagate beyond one hop. The reason is if the destination node is located within the one hop of the source, it is not wise to 'flood' the whole network. According to DSR protocol, if the first request can not help the source to discover the route, the source node will set the hop count to the highest value (which is 15) and broadcast that request packet in the network so that all reachable nodes can receive that route request. We kept margin of another route request. Because the route request packet is some time lost due to collision or high noise level etc. In MEDSR protocol, when the source node S can not find the route after sending 3 route request messages, it will assume that the destination is not reachable with that low power level. It will initiates the next route discovery by using high power

level which corresponds to transmission range of 250 meter. Now the request packet sent by the source node S can reach the neighbor node C. The whole process of handling route request is similar to that explained in the previous subsection. The only difference is that the transmit power level is high in this case and that high power level is recorded in the route request packet. When the route request packet reaches the destination node D, it sends reply packet to source node S. The reply process is also similar to the route reply process in low power level. The only difference is that the power level is high in this case.

The advantages of two power levels used in the MEDSR protocol is that network connectivity is maintained. Thus it solves the network partitioning problem, which is a usual phenomenon in most of the energy saving routing protocol which use low transmit power to save energy. Only two power levels are used to discover route compared to 6-7 power levels used in [6]. Since the power level information is recorded in the power table, the size of the packet is less compared to the packet size in [4]. Because in [4], each data packet contains information of power levels of each hops in addition to the source route. But in MEDSR protocol, there is only one field created to store the information of power level. The power table is maintained locally by each node. Storing data in the power table and retrieving data from the power table do not consume much processing power of mobile node. Moreover, the MEDSR protocol does not require any additional hardware such as GPS system. Thus the requirement of additional software and hardware have been eliminated in MEDSR protocol.

C. Example of energy saving in MEDSR protocol

In order to have an estimation of how much energy can be saved in the MEDSR protocol compared to DSR protocol, we create a simple scenario which is illustrated in Figure 4. Here we will use the energy model that we derived in section 2. In that figure the source node S has discovered routes to the destination node D. The solid-thick line shows the route $S-B-D$ discovered by the source using the regular DSR protocol. If the source node sends 100 data packets and if each data packet has a size of 512 bytes, the total energy consumption can be determined by using Equation 7. The total energy consumed while transmitting packet is equal to 0.127 Joules. For simplicity of our analysis, we neglect the energy consumption that a node spent while receiving a packet. On the other hand the dashed line shows the alternate route discovered by using MEDSR protocol using low power level. In that case, the source S has discovered the route $S-A-B-C-D$ at low power level. The distances between the nodes are shown in that figure. The total energy consumption in this case is determined by Equation 8 and the total energy consumption is equal to 0.02084 Joules. Thus almost 83% of energy has been saved in MEDSR protocol compared to its DSR counterpart. Even if the nodes A and C were not present, MEDSR protocol would discover path $S-B-D$ using high power level. In that case routes discovered by using MEDSR protocol and the DSR protocol are same. But still the energy saving could be possible because of link by link power adjustment. Using the same procedure of calculation, it can be easily shown that almost 50 % energy could have been saved in MEDSR protocol compared to DSR protocol. Although, we show some simple example, in random network the analysis will be more complicated. Usually in random network, more than one connections operate simultaneously. That is why some routes are be discovered at low power, whereas some other routes are discovered at high power level etc. Moreover, if some route request packets are lost due to collisions etc., not many routes can be discovered using low power level. In order to test the performance of MEDSR protocol in more complex network, we use Network Simulator (NS-2) [18] in order to test our algorithm for random networks.

V. Simulation Results

We test the performance of MEDSR protocol by using NS-2. Twenty pair of UDP connections are set-up randomly in the network. Constant Bit (CBR) traffic is used for generating data packet rate of 1 packet/sect. Each CBR traffic starts at random time during the simulation period. We analyze the performance of MEDSR protocol with two different types of energy constraints- (1) mobile nodes are assigned a large amount of energy and the simulation is run for a limited period of time, and (2) mobile nodes are assigned a very limited initial energy and the simulation is run for a long period of time.

A. Case I

In the first case, we assign a large initial energy and run the simulations for a limited time. The reason of assigning the large amount of initial energy is to ensure no mobile node exhausts battery during the simulation time. Thus the connectivity of the network is maintained during the simulation period. This gives us an estimate about how much energy is consumed by data packet while traveling from a source to its destination. We randomly place 100 mobile nodes in an area of 500m by 500m area. By keeping the number of mobile nodes and the number of connections, we increase the network area to 1000m by 1000m, 1250 m by 1250m and 1500m by 1500m. The initial energy is set to 2000 Joules. Each simulation is run for 250 second. Ten different topologies are generated for a given network size and the results show the average of all those ten simulations. The energy spent per data packet for DSR protocol and MEDSR protocol are shown in Figure 5. From that figure, it can be concluded that the energy consumption per data packet is always less in MEDSR protocol compared to DSR protocol. The energy consumption per data packet increases in both DSR protocol and MEDSR protocol as the network size increase. The reason is that the data packets are traveling more hops in both protocols when we place the same number of node in a larger network size. The percentage of energy saving in MEDSR protocol compared to DSR protocol is shown in Figure 6. It is shown that the energy saving is maximum when the network size is small which is almost 55 % when the network size is 500m by 500m. That saving in energy decreases with the network size. When the network size is 1500m by 1500m, the energy saving in MEDSR protocol is nearly 30 %.

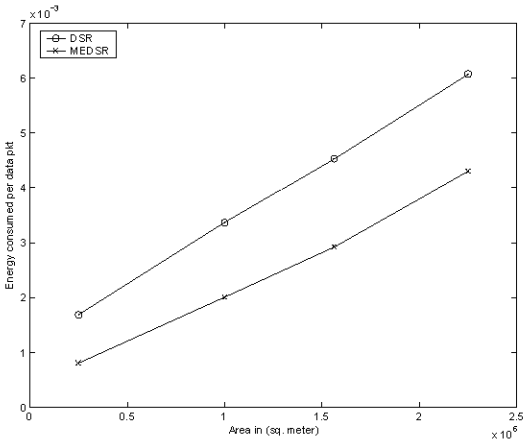

Fig. 5. Energy consumption per data packet is DSR and MEDSR

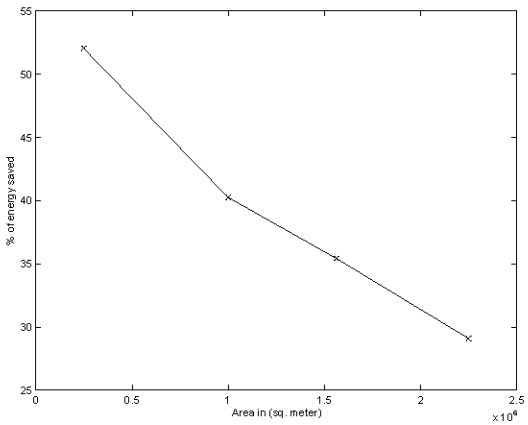

Fig. 6. Percentage of energy saving in MEDSR

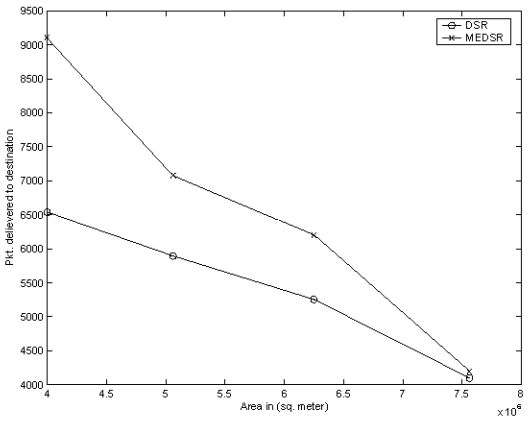

Fig. 7. Data packet delivered in DSR and MEDSR

B. Case II

In the he second case, we randomly place 100 nodes in an area of 2000m by 2000m. The other parameters are same as in the previous simulation. Only the network area is increased in this case to ensure that more number of nodes participate in the network operation. We assign a limited initial energy of 20 Joules to each mobile node and run the simulations for 5000 seconds. The packet transfer stops at certain point during the simulation when all connections are disconnected due to node failures. This gives us an estimate about how many data packets can be sent successfully to the destination by a particular network when the mobile nodes have very limited batteries. The simulations results are shown in Figure 7. It can be concluded from that figure that when the network size is the smallest which is 2000 m by 2000 m, almost 40 % more data packet was delivered to the destination by using the MEDSR protocol. We then increase the network area to 2250m by 2250m, 2500m by 2500m, and 2750m by 2750m. When the network gets larger, the number of data packet delivered of MEDSR protocol and DSR protocol becomes similar. The reason is the average link distance between a source and a destination increases with the network size. Thus the number of hops traveled by the data packets is similar in both DSR and MEDSR protocol. Moreover, the hop length also become same in both protocols. That is why almost same number of data packets are delivered to the destination in both DSR protocol and the MEDSR protocol.

VI. Conclusion

In this paper, a minimum energy dynamic source routing (MEDSR) has been introduced. It is shown that conventional routing protocol for ad hoc network use maximum transmit power or fixed power which is not energy efficient. If minimum power is used instead of fixed power, a significant amount of energy can be saved. Both analytical and simulation results show that by using the minimum transmit power, network life can be maximized and more useful data packet can to delivered to destination. One major limitations of MEDSR protocol is that the data packets travels larger number of hops compared to DSR protocol. That is why the delay per data packet can be increased. In order to improve delay, the route selection algorithm of MEDSR can be modified so that routes which lie along the less congested area of the network can be selected. In our previous work [16], we show that by choosing routing path in the less congested area can improve the delay significantly. To make the MEDSR protocol congestion aware is left as a future work. The performances of MEDSR protocol needs to be compared with to other energy aware routing protocols in order to see its advantages.

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